1998-1999 Vol. XXXI

TSUNAMI NEWSLETTER

INTERNATIONAL TSUNAMI INFORMATION CENTER - ITIC

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COMMENTS FROM THE ITIC DIRECTOR, MIKE BLACKFORD

This issue is the last “thick” issue of the “Tsunami Newsletter” that has come to be standard over the last several years. Future issues of the Newsletter will be in the leaner 4-, 6-, or 8-page format, depending on the amount of news, and they will be published bimonthly, in the odd months of the year. We want to be able to provide a timelier hard copy publication of tsunami-related news and information to those who don’t have access to the electronic media or who simply wish to archive for future reference the news and information in a less volatile media.

Early in 2001, the ITIC will begin publication of the “ITSU/ITIC Annual”, which will be a self-contained reference to the Tsunami Warning System in the Pacific (ITSU). By “self-contained” I mean the reader should be able to look in any issue of the Annual and obtain basic information on the structure and functions of ITSU, its officers, its Member States and their representatives, and its affiliation with UNESCO’s Intergovernmental Oceanographic Commission. The document will tend to focus more on the warning, preparedness, and mitigation aspects of tsunamis, however, the research aspects of tsunamis, both theoretical and applied, will not be overlooked.

It is somewhat ironic that none of the four events that occurred during the period covered by this Newsletter, for which the Pacific Tsunami Warning issued limited tsunami warnings and watches, generated tsunamis. During the same period we had the very disasterous tsunami in Papua New Guinea and the much smaller but nevertheless destructive tsunami in the Marquesas Islands of French Polynesia. These events reemphasize the need to focus some of our efforts in tsunami research on how we can better recognize this type of tsunami hazard and be prepared for it. There may be many more places in the Pacific, or in the rest of the world for that matter, that have a much more serious local tsunami hazard than we can conceive at this time.

NATIONAL REPORTS

The following are edited summaries of the national reports presented at the ITSU meeting in Seoul, Korea, January 2000. All countries that are members of ITSU are listed whether or not they submitted a report.

AUSTRALIA

Member Since:1986
National Contact: A. Bruce Neal
Status in 1999:

The main focus of activity in Australia since ITSU-XVI has been the development of an improved national warning system, known as the Australian Tsunami Warning System (ATWS). It integrates the input from the ITSU warning system for Australia's Pacific Ocean coast into a national warning system for the whole Australian coast, which is vulnerable to tsunamis from the Indian and Southern Oceans as well as from the Pacific.

A recent report commissioned by the Australian Committee for the International Decade of Natural Disaster Reduction (IDNDR), *Contemporary Assessment of Tsunami Risk and Implications for Early Warnings for Australia and its Island Territories* has shown that the two highest areas of risk in Australia are along the north-west and south-east coasts. The northwest coast is a region of considerable economic importance. The oil and gas industry and associated shore-side facilities which are located in that area are clearly at risk of major damage from tsunamis that may be generated in the Indonesian Arc. The southeast coast, mainly from southern New South Wales to southern Queensland, is Australia's most demographically important coastal region, and includes the major population and industrial areas of Wollongong-Sydney-Newcastle (population 5 million).

The Australian Tsunami Warning System (ATWS) is a collaborative operation between:

1. The Australian Geological Survey Organisation (AGSO) which has the responsibility for the Australian seismic detection network and whose Seismological Centre provides the initial alert that a potentially tsunamigenic event has occurred in an area likely to endanger Australia;
2. The National Tidal Facility (NTF) which monitors buoys and tide gauges for tsunamis via its Australian tide gauge and can undertake modeling studies of the wave run up onto the continental shelf and the coast;
3. The Bureau of Meteorology, which has responsibility for issuing tsunami warnings to the Australian community based on the information and alerts from AGSO and the NTF and action in response to the warnings and advices from the Pacific Tsunami Warning Centre (PTWC); and
4. Emergency Management Australia (EMA), which through its National Emergency Management Coordination Centre informs the emergency management authorities in the Australian States/Territories of a tsunami advice or warning and also provides expertise in overall disaster management strategies as they relate to tsunamis, particularly on disaster prevention, preparedness, response and recovery matters.

The operation of the Australian Tsunami Warning System is coordinated and reviewed by a steering committee comprising representatives of the above four agencies. Plans for streamlining the internal operational arrangements for the warning system have been developed, and a proposal is being developed to seek approval to formally establish an Australian Tsunami Warning Centre, probably in Melbourne. This would concentrate expertise, scientific support and communications in one functional centre. At the present time, most of the plans for streamlining warning operations are still dependent on obtaining funding approvals.

There is very good cooperation between the various agencies involved in the operation of the Australian Tsunami Warning System. A major weakness of the system is the lack of any coordinated warning system input from the Indian Ocean Rim countries analogous to the system that operates for the Pacific. The other weaknesses are mainly associated with the lack of an adequate sea level monitoring network to detect tsunamis in the oceans surrounding Australia (especially in the Indian and Southern Oceans). The lack of wave run-up information for Australia's very long coastline, and the overall chronic warning system problems associated with minimizing false alarms and achieving a rapid community response are also weaknesses.

On 25 March 1998 an earthquake of magnitude 7.9 occurred on the Pacific-Antarctic Ridge near the Balleny Islands, at 63º S, 151º E, well south of Tasmania. An earthquake of this size is uncommon for this region, so there was a great deal of uncertainty about the potential for tsunami generation on southern Australian coasts. A tsunami warning was issued for southeast Tasmania, and small tsunamis of the order of 5-10mm were recorded at gauges in southern Australia.

On 9 November 1998 a magnitude 6.7 earthquake occurred in the Banda Sea, about 4OOkm north of Darwin. Earthquakes in this area are common, but generally not tsunamigenic. Seismological advice suggested that the likelihood of a tsunami on Australia's north and northwest coasts was small but with a reasonable risk existing near the North West Cape. A qualified tsunami warning was issued for a small area of the far northwest coast in Western Australia. Tide gauges in northern Australia registered tsunamis of around 10mm.

A Tsunami Warning Workshop will be held in the second half of 2000 to bring together response agencies, ATWS managers, operational staff and geophysicists, with the aim of further improving the effectiveness of Australia's national and local tsunami warning and disaster response plans.

The recent experiences of the tsunamis in the Australian region, including public reactions to the disastrous Aitape tsunami of July 1998, and the minor tsunamis in Australia referenced earlier in this report, highlight the need for improved public information material. Response agencies, local authorities and the media have a significant need for such material. The ATWS intends to develop more of this kind of material for Australia, utilizing the work done in this area by other countries participating in ITSU.

At the IOC meeting on developing an Indian Ocean GOOS, held in Perth on 16-17 September, the lack of development of an integrated tsunami warning system for the Indian Ocean Rim was identified as an area of major concern. It is recognized that this will be a very difficult matter to address. However, if the development of an Australian Tsunami Warning Centre proceeds under the emerging Australian Tsunami Warning System, there would be a link established between tsunami warning systems for the Pacific and the eastern rim of the Indian Ocean. This could be a platform for expansion of ITSU activities, in consultation with the Indian Ocean Rim countries.

CANADA

Member Since: 1968
National Contact: Fred Stephenson
Status in 1999:

The Canadian Hydrographic Service (CHS) has upgraded its three tsunami warning stations by installing new data loggers and transmitting the data directly to the Institute of Ocean Sciences (IOS) using Mobile Satellite (MSAT) communication. The three upgraded tsunami warning stations are now fully operational in support of Canada's contribution to the Pacific Tsunami Warning System. As part of this upgrade, tsunami warning capability was transferred from Bamfield to Tofino. No changes were made to the locations of the other two stations at Winter Harbour and Langara Island.

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The stations at Tofino and Winter Harbour now have both a telephone modem and a satellite link. Designated personnel will use telephone modem and/or MSAT software to establish a link with each station. Either method can be used. At each of these sites a Sutron model 8210 data logger is interfaced to two float and counterweight equipped encoders. Water levels are measured continuously, although only one minute integrated values are stored. Also recorded with each sample is the maximum deviation from the mean.

At Langara Island, normal tsunami communications will use the satellite link. The remote data recorder is also linked to the Coast Guard lighthouse via a high quality telephone cable (1 kilometre), 2 modems, a ring simulator and a laptop computer. This system serves as a backup to the MSAT link. In the event of a satellite failure the lighthouse attendant will be notified by CHS personnel via the Prince Rupert Coast Guard VHF radio telephone service. Using the PC/ modem/land-line link the attendant will establish communication with the gauge and monitor the water levels throughout the tsunami warning/watch period. The attendant will contact CHS via the Prince Rupert Coast Guard VHF radio telephone service to report on observed arrival times and heights. The Langara station uses the same data logger and sampling scheme as the other two stations, however, it is interfaced to a bubbler system and a Paroscientific differential pressure sensor. Software at the Langara site has been modified so that the two modes of communication (modem and MSAT) can be used simultaneously. This allows both the lighthouse attendant and CHS staff to monitor the water level information continuously during a tsunami warming/watch.

In early 1999 the CHS tsunami warning system was determined to be a Y2K critical application and an extensive contingency plan was developed. As part of the contingency planning process for the tsunami warning stations, upgrades were also made to the computers and associated infrastructure (power supplies, telephone lines etc.) used by the CHS to receive, process and disseminate the tsunami/water level information. All required Y2K modifications and upgrades are now complete.

In the event of a Tsunami Warning, or Watch, the Provincial Emergency Plan (PEP) will provide CHS with the location and magnitude of the earthquake. Designated CHS staff can be notified 24hrs/dav by home telephone, dedicated CHS tsunami telephone and/or pager. Working from home or from the office CHS staff will use tsunami travel time charts to determine or confirm the expected arrival times for Langara, Winter Harbour and Tofino. The predicted water level for each of these stations will be determined based on the expected arrival times. Each station will be accessed by both telephone and MSAT to ensure it is operational. As the expected tsunami arrival time nears each station will be continuously accessed to monitor the time and height of the event. Throughout this period all pertinent information will be telephoned and faxed to PEP.

Within a few months the system will also be capable of automatically forwarding event alarms and coincident predicted water levels directly to an alphanumeric pager. Future enhancements will provide the capability to access the IOS tsunami computer by laptop or palmtop computer using a cellular phone. This will provide immediate access to the data and station parameters, including the ability to change the station parameters. Another enhancement which still needs to be investigated and developed is to have incoming data automatically placed on a web site for reference by selected users (ATWC, PTWC, PEP etc.)

A tsunami watch was issued for the northern BC Coast following a magnitude 7.7 earthquake that occurred near Kamchatka at 0327 PST on December 5, 1997. Upon being notified by PEP, CHS staff immediately proceeded to IOS in support of the province's tsunami response plan. Tsunami and Permanent Water Level Network stations were polled and checked in preparation for a possible tsunami. PEP was provided with information on predicted tide heights along the BC coast, and estimated tsunami arrival times for various locations on the BC coast were prepared using results from previous modeling. The Tsunami Watch was cancelled

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at 0555 PST, however, a magnitude 6.5 aftershock occurred at 1048 PST. CHS staff remained in a state of readiness during this period. Interviews were provided to radio stations and newspapers.

Notification of all communication tests initiated by ATWC, as well as summaries of these tests, are received and reviewed by the CHS on a regular basis. During the period September 1997 - August 1999 response times for the ATWC dissemination tests were typically less than five minutes at both CAA FSS Prince Rupert and PEP. At MARPACHQ Esquimalt, which receives its messages by AUTODIN, the response times were often less than 30 minutes: however, they were sometimes in excess of 90 minutes. Response times for the tide station at Prince Rupert were usually less than 10 minutes.

The Provincial Emergency Program (PEP) has a Tsunami Warning Plan for the BC coast. In this plan, the Canadian Hydrographic Service is tasked with providing information on tsunami from tide stations, and with providing forecast information based on results of numerical model simulations, data obtained from other stations (provided by PTWC and/or ATWC), and tidal predictions. Canada, through PEP, along with the state governments of Alaska, Washington, Oregon and California continues to work closely with the ATWC to improve tsunami response in the Northeast Pacific.

The CHS tsunami response, in support of the Provincial Emergency Program, is provided by a core staff of three individuals who can be reached by telephone or pager at any time and provide the initial response and decision making advice. In support of this role the CHS continues to use a package developed using FrameMaker for process control in the event of a tsunami watch or warning. Hypertext links allow fast access to information at a level of detail necessary to carry out the appropriate response. For the past few years PEP has been instructed to contact the CHS whenever an earthquake of magnitude 6.5 or greater is observed anywhere in the Pacific. Most of these events do not generate tsunami warnings or watches; however, the communication tests are extremely useful.

Regional response to earthquakes. tsunami, and other emergencies is coordinated, in part, through meetings of the BC Earthquake and Tsunami Working Group and the BC Regional Emergency Telecommunications Committee. The Earthquake and Tsunami Working Group last met in February 1997. As January 2000 marks the 300th anniversary of the last great Cascadia Subduction Zone earthquake it's anticipated that the Working Group will meet again before then.

The Western States Seismic Policy Council met in Victoria in November 1997. This meeting featured a session on tsunami which was attended by staff from both CHS and PEP.

An international workshop on bathymetry and coastal topography data management was held in Seattle, Washington in March 1998. The Canadian representative to ICG/ITSU attended this workshop and a follow-up meeting held during the IUGG XXII General Assembly in July 1999.

Over the past two years there has been some modelling done to study the possible generation of tsunami due to underwater slide generation at several locations in the Strait of Georgia. Present efforts are directed at obtaining funding (from the Coast Guard) to study the effects of tsunami as they relate to Search and Rescue.

It is now widely recognized that megathrust earthquakes occur along the Cascadia Subduction Zone, and that the last of these earthquakes may have occurred in January 1700. These findings have produced a great deal of interest. Much of the public education for earthquake preparedness is provided by staff of the Pacific Geoscience Centre, and experts from the Institute of Ocean Sciences regularly provide information on tsunamis and tsunami response to researchers, schools, insurance industry representatives, the press, and the general public. A National Geographic Society Teacher's Guide for tsunami was reviewed in 1998. The chapter on tsunami is part of a larger package intended for distribution by CD.

As part of the public education program, all telephone directories for communities in BC coastal areas contain information on earthquake and tsunami response.

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CHILE

Member Since: 1968
National Contact: Rafael Mac-Kay
Status in 1999:

The Chilean National Tsunami Warning System (Sistema Nacional de Alerta de Maremotos - SNAM) is operated by the Hydrographic and Oceanographic Service of the Chilean Navy (SHOA). SHOA is responsible for the maintenance of the sea level network along the Chilean coast and the "El Roble" TREMORS station. During the intersessional period, there have been no local tsunamigenic earthquakes.

The TREMORS system was installed in 1995 with 3 broadband displacement sensors, which were not able to properly record the local seismic activity (epicentral distance < 300 km). For this reason and after serious research conducted by LDG (France), the station has been complemented with a new system that includes 3 accelerographs. The link to download the signals from this station to SHOA office will be installed soon. Another problem solved during this period was the lack of azimuth resolution from seismic waves coming from events located northward. A refined version of the software provided by the TREMORS personnel ended this inaccuracy.

The sea-level network has been upgraded with the help of PTWC. New HANDAR 555C type stations have been installed. At present there are 17 sites along the coast with this type of sensor utilizing satellite communication, replacing in most cases the old bubble Metercraft tide gauges. The total number of active sea-level stations in Chile is 21. An upgrade of the satellite receiver station is planned in the near future.

The national seismic network run by the Seismological Service of Universidad de Chile has been improved in several regions of the country during the intersessional period. The northern seismic network actually has 12 short period digital stations operating between latitudes 17.6° S and 20.2° S, and 1 broadband station is under construction (Iquique) Another local seismic network with 9 short period stations and 1 broadband station operates between latitudes 22° S and 24.5° S. In central Chile the seismic network has 13 short period stations and 4 broadband stations (including the TREMORS system) located between latitudes 32.8° S and 34.5° S. This network will be improved by adding more stations to extend coverage to the north and south of the present area. Another local seismic network is under construction in the southern central part of the country between latitudes 35° S and 37.5° S with 5 broadband stations.

Complementary to improved communications with PTWC, Chile installed in 1998, a terminal of the US operated communications system, Emergency Managers Weather Information Network (EMWIN), which can provide various emergency management data like warnings and watches from PTWC through the GOES satellite system.

The new seismic and sea level acquisition technology has motivated an update of the internal SNAM operating procedures in case earthquakes occur in the country. Such procedures establish specific duties and responsibilities during different stages in the operation of the system. The modifications are mainly related to the rapid seismic data collection with the new short period digital seismograph and the capacity of accessing data collected by the HANDAR sea-level stations in near real-time.

A formal agreement between the SHOA and the Dirección de Hidrografía y Navegación de la Marina de Guerra del Perú was reached during 1999, to perform monthly tsunami dummy exercises and exchange of the data of the corresponding TREMORS stations. The objective of the exercises is to improve the response of the operation of both national tsunami warning systems in case a tsunamigenic earthquake takes place in the region.

SHOA, as the institution responsible for maintaining and operating the National Tsunami Warning System, monthly conducts communication exercises with all tide stations. To keep the system under control; watchmen properly trained, test the time involved in the implementation of tsunami warning and watch messages. The results have shown a systematic reduction in time and an increased understanding and level of interest by the watchstanders in charge of tide gauges. With the new technology in place, tide gauge watchstanders will provide complementary information based on direct tide staff observations.

The CITSU project "Processing of Inundation Maps by Tsunamis for the Chilean Coast", following the techniques of the TIME project, has been under development during the intersessional period. Maps of the following ports have been produced and published: Arica, Iquique, Antofagasta, Mejillones, Tocopilla and Caldera. Chile contributed additions, modifications and corrections to the final version of this publication. Today it can be found at the ITIC web page (http://www.shoa.cl/oceano/itic/frontpage.html), in Spanish and in English. SHOA is now working on more detailed tsunami inundation maps for the urban areas located inside the bays of Valparaiso and Concepción.

During the intersessional period, Chile was represented in several national and international meetings. We attended the international conference, "Modern Preparation and Response Systems for Earthquake, Tsunami and Volcanic Hazards", held in Santiago, Chile in April 1998 and the "International IDNDR Conference on Early Warning Systems for the Reduction of Natural Disasters (EWC'98)" held in Potsdam, Germany in September 1998. We also attended the "Natural Hazards Congress" held in Buenos Aires, Argentina in June, 1999. We have taken advantage of all these opportunities to highlight the importance of the Tsunami Programme of the IOC and we have shared our experience.

Chile also contributed materials for the exhibition at the UN Pavilion of the EXPO 98, held in Lisbon, Portugal.

Chile has actively participated as the Regional Tsunami Co-ordinator for the ETDB, and is under permanent contact with Project Leader. Contacts have been established with Centro Regional de Sismología (CERESIS) in Lima, Perú to revise the tsunami data for South America.

After the nomination of Lt. Cdr. Rodrigo Nuñez as the Associate Director of ITIC, he paid a short visit to the ITIC headquarters, to start exercising the responsibilities of the appointment. He designed and prepared the ITIC home page, a major contribution to ITIC and it's role in making information to the tsunami community more accessible and timely. During the intersessional period the terms of reference and responsibilities of the Associate Director were established by the parts.

CHINA

Member Since: 1968
National Contact: Luo Yuru
Status in 1999:Unknown, no National Report received.

COLOMBIA

Member Since: 1980
National Contact: Hansjurgen Meyer
Status in 1999:

The 'Comision Tecnica de Alerta de Tsunami' - CTAT - (Comision Colombiana de Oceanografia), the body which coordinates the activities of the Colombian institutions involved in tsunami risk reduction projects meet, on average, every 4 months. Presently, its main task is the formulation of the sectors on tsunami for the recently adopted National Disaster Prevention and Management Plan; among the objectives of this sub-plan is to serve as a basis for budget allocations.

Colombia's most important tide gauge station for tsunami observation, located in the port of Tumaco, has been upgraded recently. Now its data is being transmitted over the

GOES satellite to the headquarters of IDEAM in Bogota and there put on a WWW page within an hour. Before the end of 1999, the station housing, which sustained significant damage during the local tsunamigenic earthquakes, will be replaced with a new, resistant structure. Also, efforts are underway to replace the mechanical part of the system (stilling well, floater, drum recorder) with more advanced and resistant devices.

The bridge linking the 2 main islands of Tumaco, damaged during the 1979 event has been reinforced and broadened (1998). The project aimed at broadening the bridge linking the islands with the mainland, the only possible evacuation route, is still awaiting funding.

The Colombian-European project for the re-orientation of urban development in Tumaco, shall resettle the 3,500 most vulnerable families, living presently on the seaward shore, as well as create a new urban centre on the mainland. It has already taken care of 800 families.

An NGO-financed project to resettle again the settlement following the 1979 devastation of San Juan de la Costa (about 50 kms north of Tumaco) is underway for several hundred families.

The project to install a TREMORS station had to be postponed for several years due to funding limitations. A broadband seismic station has now been purchased for this purpose; it is due for installation at the end of 1999.

In early December 1999, a series of presentations will be given in Tumaco to commemorate the occurrence of the 1979 tsunami and earthquake and to disseminate information about the status of the national tsunami prevention project.

Messages received from PTWC, including the watch/warning for the September 1999 Taiwan earthquake, have been received at OSSO (via fax and e-mall). They were evaluated in terms of the local exposure and risk (based on historical information and results of inundation modeling), and then communicated to all responsible and interested national and local institutions.

Colombia has offered, through the Comision Colombiana de Oceanografica and the Ministry of Foreign Relations, to host the Eighteenth Session of the ICG/ITSU, in Cartagena. The invitation has been welcomed by the IOC Secretariat.

Based on software and training provided by the TIME project, as well as resources from Swiss cooperating agencies, OSSO has continued working on inundation modeling, mainly for the two areas of highest risk, Tumaco and Buenaventura. Preliminary models have been published; on-going work concentrates on incorporating higher resolution bathymetry and modeling critical local features, such as barrier islands and intertidal flats.

COOK ISLANDS

Member Since: 1980
National Contact: Tere Bishop
Status in 1999:Unknown, no National Report received.

COSTA RICA

Member Since: 1991
National Contact: Alejandro B. Gutierrez
Status in 1999:

Costa Rica has five automatic tide gauges in operation. These instruments also measure and record the main atmospheric variables as well as the SST and SLP. Four are installed along the Pacific coast and one on the Caribbean coast. At present data is recorded every hour. The satellite transmission system has some problems, which are going to be solved shortly. It is necessary to get funding to improve the stations, so the sampling rate during a "tsunami event" could be reprogrammed. The National University’s International Ocean Sciences Institute archives the data from these stations.

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Included in a project of the United States' NOAA to help reconstruct the Central American monitoring system, is a plan to reestablish the sea level measurement network. Costa Rica will most likely participate in this effort, which is to begin in the near future. This project will install or maintain at least two stations per country. Also, it is expected that the systems will be set up in such a way that the maximum amount of information could be recorded at each station, including sea level measurements with the capability to switch sampling rate during tsunami events. At present, Belice has one tide gauge in operation. Nicaragua has three in the Pacific, but there is no information about their operational status. The instruments are new and it is not known if they were leveled. This detail has to be incorporated in the new project. Panama, as is well known, has a station at Balboa on the Pacific coast, and, I have to mention, the same for Coco Solo. Now that the Canal will be transferred, there is a need for special attention to assure that no potential gaps occur with the time series. El Salvador, Honduras and Guatemala don't have any operational tide gauges at this time.

Costa Rica hopes to participate more actively in ITSU forums in the future. It is also seeking ways to get the local authorities more involved with this process so they will support a regional presence at ITSU forums. Costa Rica would like to see improvements in the two-way communication between itself and the operational elements of ITSU in contrast to the current one-way communication. Costa Rica receives information about the tsunami events, but they are not queried about the effects of the event when it happens locally in Central America. Implementation of this last point should provide incentive for development of the "eventual" Central American Network that can, in turn, provide critical information to the system ITSU coordinates.

ECUADOR

Member Since: 1978
National Contact: Fausto Lopez-Villegas
Status in 1999: Unknown, no National Report received.

FIJI

Member Since: 1978
National Contact: R. A. Rahiman
Status in 1999: Unknown, no National Report received.

FRANCE

Member Since: 1968
National Contact: Francois Schindele
Status in 1999:

Since 1997, the Laboratoire de Géophysique (LDG) has been improving the development and implementations of the TREMORS system. LDG was also involved in numerical simulations of tsunamis induced by earthquakes and tsunamis produced by submarine landslides.

New TREMORS stations have been established in Korea and in Peru. The TREMORS software has been adapted to the IRIS real-time format (MINI-SEED, 5Hz serial line) with the co-operation of PTWC and IRIS. This format was ungraded twice in 1998 and 1999. The TREMORS software is operating at PTWC (in Hawaii) since November 1996, in IGP and DHN (Peru) since November 1997 and in Korea since April 1998.

Numerous tsunami simulations were undertaken by LDG during 1997-1999. LDG is involved in the study of both tsunamis produced by submarine landslides and tsunamis induced by earthquakes. Numerical simulations of tsunamis in the Pacific Ocean and in the Caribbean Sea are presented in this report.

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On 21 February 1996, an earthquake with magnitude Mw of 7.5 occurred off the coast of Peru. This event was a «tsunami earthquake» not felt by coastal communities. The surface magnitude, Mb, of this event was only 5.8. This earthquake generated a tsunami of 148 cm wave height in Chimbote and run-up from 2 to 5 meters along the coast. 13 hours, 00 min later, the tsunami reached the Marquesas Islands (French Polynesia) and particularly Hiva-Oa where wave heights of about 1 to 2 meters were observed in the harbour of Tahauku Bay.

The ground deformation has been calculated using Okada's formulas (1985) based on the seismic parameters determined by Ruegg and Manfret. The propagation of waves traveling the Pacific Ocean is simulated using a grid of 2000x1000 cells with a grid space step of 5 km. A second grid covering the Northern coast of Peru is used to study the propagation along the Peruvian coast. The number of cells is 700x2100 with a grid size of 1 km.

The high waves observed in the Marquesas Islands seem due to local effects and not to the gradual submarine slopes ranging from 5° to 10°, steeper than the ones of Hawaii. The other archipelagos of French Polynesia (Gambier, Society Islands, Austral Islands or Tuamotu) present steep slopes around 30° and were not affected by this tsunami. In order to study the effects of local bathymetry, coupling between coarse and fine grids has been carried out in the island of Hiva-Oa, where one of the most violent phases of the tsunami was filmed during about 10 min showing the Bay of Tahauku and its small harbour. The length of this Bay is about 1 km, the width at the mouth is about 500 meters. At its maximum level, the tsunami penetrated about 150 m the mouth of Tahauku river and inundated 20,000 m^2 of land.

The numerical simulation of these phenomena in the harbour of Tahauku Bay has required the coupling between four grids. The finest grid increment is 10 m in the fourth grid covering the Bay of Tahauku. In order to take into account the dense vegetation on land, Chezy coefficients have been introduced according to Mader's study (1991) in Hawaii for the 1946 tsunami.

The computed maximum and minimum sea levels match very well the observations as regards the maximum crest-to-trough wave heights close to the breakwater and the maximum run-up and run-down distances. The breakwater plays the part of a dam when the sea-level withdraws, the sea-level outside the harbour is lower than inside. The observed large eddies generated by the breakwater are also well reproduced by the model.

On 4 October 1994, an earthquake of magnitude Mw = 8.2 occurred in the western part of the Kurile Islands, generating a tsunami that has been well recorded along the entire coast of Japan. Previous works have shown that this earthquake does not present a low angle thrust event, normally expected in a subduction zone, rather an intra-plate event rupturing through the slab. On the basis of the accepted mechanism, two fault models, representative of the nodal plane ambiguity, have been suggested. The goal was to verify whether the tsunami simulations are able to rule out one of the two proposed fault models. Taking into account both fault models together with a heterogeneous slip along the fault, we have performed numerical simulations of the tsunami. All source models produce tide-gauge records, in agreement with the observed ones. The limit of resolution of the performed simulations, estimated by means of a perturbed bathymetry, does not allow us to distinguish the best source model.

The Soufriere Hills volcano, in the island of Montserrat (Caribbean Sea), has been erupting since July 1995. Ten people have been killed by a debris avalanche on 25 June 1997. The evolution of the volcano activity could lead to the collapse of a portion of the lava dome and to a sudden entry of debris avalanche into the Caribbean Sea. In the worst case scenario, the volume of material reaching the sea has been estimated at 80 millions of cubic meters. The aim of this paper is to assess the hydraulic phenomena in the Caribbean Sea related to this potential aerial landslide on Montserrat.

The sliding of this mass and the generated water surface have been simulated numerically, assuming that the debris behave like a fluid of density 2 flowing into the sea. The numerical model solves the 3D Navier-Stokes equations for a mixture composed of sediments and water. The bathymetry and topography have been also simplified as shown on the figure. The debris are assumed to enter the sea at the initial instant with a front height of 50m and with an impact velocity of 50 m/sec. This latter value has been estimated from the observed and calculated velocities for the first Mt. St. Helens rockslide avalanche of 1980 (Sousa and Voight, 1995).

One national conference of note was held in Paris in June 1999. The DASE had a poster on tsunami hazard in French Polynesia and Caribbean Sea at this conference.

Following the decision made at ICG/ITSU-XVI, Mr. Schindele from LDG, France, incorporated the comments made by the group during ITSU-XVI and prepared the new version. This version was translated in French and published. The IOC French Delegation and the French Ministry of Foreign Office supported the publication of the brochure.

GUATEMALA

Member Since: UNK
National Contact: Eddie Hardie Sanchez-Bennet
Status in 1999: Unknown, no National Report received.

INDONESIA

Member Since: 1980
National Contact: Ibnu Purwana
Status in 1999:

In Indonesia, The Meteorological and Geophysical Agency or Badan Meteorologi dan Geofisika (BMG) is the agency responsible for operational activities in the fields of meteorology and geophysics. These include monitoring of tectonic earthquakes and any resulting tsunamis. For this purpose, BMG currently operates 61 seismic stations consisting of 31 telemetry stations and 30 man-operated stations. All of these stations operate short period vertical component seismometers. In addition, two stations Lembang, (LEM) in West Jawa and Tretes (TRT) in East Jawa - also operate component long period seismometers. Tretes station was then improved with TREMORS (Tsunami Risk Evaluation through seismic Moment from Real-time System). The system was installed in 1996 under the technical cooperation with LDG (France). (The national report of Indonesia for the last IOC/ITSU-XVI summarizes the capability of the BMG in monitoring tectonic earthquakes and the resulting tsunamis.)

There was no significant tsunami in Indonesia during the recent intersessional period of October 1997 - September 1999. Twenty-three significant earthquakes were felt and four of them resulted in some destruction to hundreds of buildings and killed tens of people but no tsunami was generated.

An earthquake of 29 November 1998 occurred at 23:10 local time, (14:10 UTC) originating in Maluku Sea at coordinates 1.97 S - 124.92 E and at focal depth of 33 kms. As a result, 25 people were killed, 8 were missing, and 672 buildings were heavily damaged. The earthquake was of 6.5 surface magnitude (Mb), and was suspected of having a potential to generate local tsunami. The International Tsunami Information Center (ITIC) in Honolulu sent fax to BMG asking for confirmation about the tsunami, but no tsunami was confirmed. This is due to the fact that the earthquake is associated with a strike-slip mechanism of the South Sula - Sorong fault.

The government of Indonesia has established the National Coordinating Board for Disaster Management; Badan Koordinasi Nasional Penanggulangan (or Bakornas PB) which is chaired by the Minister Coordinator for People's Welfare. Bakornas PB is responsible for the disaster management activities during and after disasters. This includes activities in mitigation, relief, rehabilitation and reconstruction. BMG has actively participated in Bakomas PB, especially in the Working Group for Natural Disasters: Tectonic earthquakes, Tsunamis, Drought, Forest Fire and Flood.

In the Third Session of the Joint Working Group between the BMG and the Australian Bureau of Meteorology (BoM) on Cooperation in Meteorology, in Jakarta 11 – 13 July 1999, a cooperative agreement was made for tsunami warning. One BoM officer is to visit the Tsunami Observing Station in Tretes in the year 1999/2000.

In the framework of monitoring aftershocks of the tectonic earthquake which generated the gigantic Flores tsunami of 12 December 1992, the Department of Tsunami and Storm Surge of the Earthquake Research Institute (University of Tokyo) and BMG have jointly operated a small seismic network since 1993. The network consists of three vertical component digital seismographs installed in Maumere, Larantuka and Ruteng (all are located on Flores Island). This is mainly intended to estimate the dimensions of the fault plane based on aftershock distributions.

The future plan of the tsunami monitoring program is aimed at, 1) Improving the capability of the seismological network in order to get more rapid and more accurate epicenter determinations. 2) Strengthening inter-institutional cooperation in tsunami monitoring, and 3) setting up a comprehensive data base for historical tsunami data for a better understanding of tsunami prone areas.

JAPAN

Member Since:1968
National Contact: Itsuo Furuya
Status in 1999:

The Japan Meteorological Agency (JMA)'s new tsunami forecast service has been in effect since April 1999. The new forecast is based on computer simulations of tsunamis rather than on an empirical tsunami forecast [prediction of expected tsunami wave heights, ed.]. As a result, more effective countermeasures can be taken by disaster mitigation organizations.

The new tsunami forecast service has four aspects:

1. The initial announcement is issued about 3 minutes after an earthquake occurs. It gives a warning or an advisory of the likelihood of a tsunami.
2. Next, information on expected arrival times and maximum heights of tsunami waves, is issued in around 5 minutes after the occurrence of the earthquake.
3. Around 7 minutes after the occurrence of the earthquake, information on times of high tides in addition to the expected tsunami arrival times is issued.
4. From time to time after the first tsunami arrival is observed, information on tsunami observations is issued.

A stream of information is issued to the areas most likely to be affected by the anticipated tsunami. The times (used above) required for issuing the various types of information, is for earthquakes occurring near the coasts of Japan. For distant earthquakes, there is more time for deliberation. (The term 'tsunami forecast' bears a double meaning in this report: the literal meaning as much like a 'weather forecast', and the term indicating the first piece of information. The information issued in the first place is titled 'Tsunami Forecast' in our tsunami forecast service).

Since the JMA's tsunami forecast service began in 1952, the tsunami forecast had been principally based on the same procedures; observations, calculation of earthquake location and magnitude, judgment on tsunami generation and estimation of a tsunami size, and, if necessary, announcement of a tsunami forecast. Especially, the main procedure in a tsunami forecast, i.e., the one for judgment on tsunami generation and estimation of a tsunami size has been left unchanged, depending on experiences, though compiled in routine manuals. This is in sharp contrast to the improved methods of determining earthquake parameters, and transmitting data and information.

The new tsunami forecast is markedly different from the previous tsunami forecast. Once the location and the magnitude of an earthquake are determined, tsunami heights and tsunami arrival times are retrieved from a database quickly. If the heights exceed the warning level even at a point, a tsunami warning is quickly and automatically issued and the various pieces of tsunami information are also automatically sent through ADESS to various sections of the national and local governments in charge of disaster mitigation and the broadcasting media.

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If the properties of a fault which causes an earthquake are given, we can easily simulate a tsunami. However, error can still occur in calculating a tsunami simulation, even if performed with an up-to-date supercomputer; that being, the tsunami forecast may still not be timely enough. In order to save time for the calculation, a database was created which contains a great number of simulation results. Each result, i.e., an element of the database, consists of a location of a hypocenter, magnitude of an earthquake, tsunami heights and tsunami arrival times at various points on the coasts of Japanese main islands and the other smaller islands.

The simulation is made for faults located at 4000 points offshore with a depth of 0 km, 20 km, and 60 km, and magnitude ranging from 6.2 to 8.3 with an interval of 0.3. For a distant tsunami, we have 110 surface fault models placed along the Circum-Pacific seismic belts with magnitude of 7.5 and 8.5. A total of about 100,000 simulation results make up the database. Of course, the estimated location and magnitude of an earthquake rarely coincide exactly with one in the database, so interpolation regarding a location (latitude, longitude, depth) and magnitude is often necessary. And finally, the configurations of a fault, i.e., the length, the width and the slip of a fault, are given from the empirical formulas relating respectively with magnitude. The dip angle of 45 degrees and the slip angle of 90 degrees, i.e., a pure reverse fault, are assumed. The strike of a fault is assumed to be parallel to trenches or roughly to coastlines. Such situations are most likely the case for tsunamigenic earthquakes around the Japanese islands and on the periphery of the Pacific Ocean.

Another feature of the tsunami forecast service is micro-zoning of forecast blocks. In the previous tsunami forecast service, the Japanese coast was divided into 18 blocks, each a segment of coast several hundreds of kilometers long. Often blocks extended over prefectural boundaries, and would cause some problems. Even if, for example, the danger of tsunami was limited to a single prefecture or only smaller areas in the forecast block, a tsunami warning was issued to the block as a whole. All disaster mitigation authorities in the related block had to have their staff on alert against the danger of tsunami. Furthermore, if the danger of tsunami still remained even for a small area in the block, the tsunami warning once issued to wide areas could not be canceled very easily.

The calculation gives tsunami heights at arbitrary points. The database contains simulated tsunami heights at 600 points along the Japanese coasts for every fault out of 100,000 models. That enabled us to subdivide the previous 18 forecast blocks into smaller forecast blocks. In the present service, we have 66 tsunami forecast blocks, each corresponding mostly to a single prefecture or a smaller area.

The content of messages in the new forecast service are very different from the previous messages. The same categories are used; ‘Major Tsunami’, ‘Tsunami’ and ‘Tsunami Attention’ and ‘Major Tsunami’ and ‘Tsunami’ remain warnings, and ‘Tsunami Attention’ is still an advisory. So the wording is the same in the messaging (except the names of the tsunami forecast blocks is different). However, in the previous forecast service, ‘Major Tsunami’ meant the tsunami could exceed 3 meters in the worst case scenario, in the new service, tsunami heights are announced in the form of information which is issued in approximately 5 minutes after the occurrence of an earthquake in specific values, 0.5 m, 1 m, 2 m, 3 m, 4 m, 6 m, 8 m, and over 10 m. When the resulting value is 3 m or larger, we issue a ‘Major Tsunami’ warning; when it is 1 m or 2 m, we issue a ‘Tsunami’ warning and; when it is 0.5 m, we issue a ‘Tsunami Attention’ advisory.

The database contains more precise estimations for tsunami heights than the ones above. However, such precise values do not always match actual tsunami heights. Rather than announce specific expected wave heights, we round values into approximate values. For example, if the database value is larger than ‘about’ 20 cm and less than ‘several’ tens of centimeters, we announce the expected height is 0.5 meters in our tsunami forecast.

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To further make the new tsunami forecast service more effective to disaster mitigation, the national and local governments have been proceeding with the development of tsunami inundation maps. The inundation maps show in detail how tsunamis behave along specific coastlines and how far inundation can be expected to reach given the predicted wave heights announced in a tsunami forecast. The inundation maps are expected to be helpful to mitigate tsunami disaster in combination with the new tsunami forecast.

The software and the database have been installed on the tsunami forecasting systems at JMA Headquarters and RTWCs. The tasks for tsunami forecast there are being conducted by the staff on duty who are constantly on surveillance of seismic activity in and around Japan. Up until the writing of this report, the new tsunami forecast service has not be used for an actual event. However, we are convinced of the effectiveness of the new tsunami forecast service to mitigate tsunami disasters by producing quicker and more accurate information.

Tsunamis observed in Japan since the autumn 1997

(All of the tsunami heights given below are measurements of a half of trough-peak amplitude observed at tide stations. The occurrence of a tsunamigenic earthquake and a tsunami forecast disseminated from JMA are sent to PTWC and neighboring countries.)

1. A small tsunami was observed for the earthquake near Torishima Island on 30 September 1997. Earthquake source: Date: 30 September 1997,Time: 06:27:24.4 Latitude:31° 59.0', Longitude:142°27.0', Depth:52km, Magnitude: 6.1
   Tsunami observation : Station: Chichijima, Beginning Time: 07:22 UTC, Maximum height (at 07:35 UTC): 3 cm.
   Tsunami forecast Tsunami Attention was issued at 06:54 UTC for the Pacific Coast of Kanto and was lifted (All-Clear) at 07:31 UTC.

2. A small tsunami was observed for the earthquake far south off Ishigakijima on 3 May 1998.
   Earthquake source: Date: 3 May 1998, Time: 23:30:18.8 (UTC) Latitude: 22° 25.3'N, Longitude: 125°25.0'E, Depth: 33km, Magnitude: 7.6
   Tsunami observation (4 May 1998): Tsunami Warning was issued in some regions judging from the shallow focal depth and the large magnitude. This included a warning for the Coasts of Okinawa Islands, which went into effect at 23:39 UTC. A watch was put into affect for Kyushu coastlines (23:50 UTC) and for the Pacific Coast of Central Honshu and Shikoku (23:51 UTC). Actually, only a small tsunami was observed. The fault was revealed to be a strike-slip. The all-clear for all areas was given at 2:15 UTC.

Station	Beginning time	Maximum time	Height height
Mera	03:37	03:48	13 cm
Okada (Oshima)	03.37	03:52	11 cm
Miyakejima	03:12	03:37	11 cm
Murotomisaki	02:15	02:39	5 cm
Tosashimizu	02:33	02:41	6 cm
Aburatsu	02: 23	03:01	5 cm
Makurazaki	02:12	02:40	5 cm
Amami		01:52	4 cm
Naha		00:40	3 cm
Yonaguni		01:16	2 cm

3. A small tsunami was observed for the earthquake near north coast of Papua New Guinea on 17 July 1998
   Earthquake source: Date: 17 July 1998, Time: 08:49:13.2 (UTC) Latitude: 2° 57.7'S, Longitude: 141°55.6'E, Depth: 10km, Magnitude: 7.1
   Tsunami observation : No Tsunami forecast

Station	Beginning time	Maximumheight	
		Time	Height
Shimokita	17:17	23:09	4 cm
Hachinohe	16:47	19:45	6 cm
Ayukawa	16:18	18:25	8 cm
Mera	16:09	16:52	10 cm
Miyakejima	15:19	17:00	22 cm
Chichijima	14:51	15:39	9 cm
Irouzaki	15:30	16:42	14 cm
Owase	15:00	15:25	6 cm
Uragami	14:53	15:02	4 cm
Kushimoto	14:40	15:55	12 cm
Murotomisaki	14:58	16:07	14 cm
Tosashimizu	15:23	16:00	23 cm
Amami	14:37	14:53	14 cm

KOREA (DPRK)

Member Since: 1968
National Contact: O. Ryang Pyong
Status in 1999: Unknown, no National Report received.

KOREA (ROK)

Member Since: UNK
National Contact: Sang-Jo Kim
Status in 1999:

Since hosting Session XVII of the International Co-ordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU), The Korea Meteorological Administration (KMA) has moved ahead in strengthening its role in seismological observation, tsunami warning, and related research.

The IUGG-IOC Joint Workshop to be held in conjunction with ITSU-XVII was also a milestone in the integration and promotion of tsunami mitigation at the national level.

During the inter-sessional period, several local earthquakes and the issuance of a tsunami watch helped us to obtain some funds from our regular budget for the installation of an observing system. Now our concern is that there were two damaging tsunamis generated at north-western sea region of Japan in 1983 and 1993, and the seismic gap in the same region has been gaining the possibility of another tsunami along with time lapse.

Since January 1997, there were 83 local earthquakes with maximum magnitude of 4.2 in and around the Korean Peninsula (report includes table of events). It is notable that the number of events has increased remarkably this year, even though the magnitudes are still below 4.

The KMA once issued a Tsunami Watch in May 1998 for the earthquake occurred at south-eastern sea region of Taiwan with the following USGS data; Origin time 23:30 UTC, 05-03-98, Epicenter 22.49N, 125.30E, Depth 33 km, Magnitude 7.3Ms. [The full report provides summary of action taken during the event]. The KMA started a project for strengthening national seismological observation network and tsunami warning system in 1997. The new seismological network is composed of 12 very-broad-band seismometers, 19 short-period seismometers and 75 accelerometers, which is to be completed in 2000. This system was designed to provide an automated solution of seismic events for the immediate response to tsunamigenic earthquakes.

In 1998, KMA installed TREMORS (Tsunami Risk Evaluation through seismic MOment from Real-time System) in co-operation with the LDG of France.

Another project for tsunami warning is to install a sea-level monitoring system at Ulleung-Do, an island located about 130km off from the eastern coast, which will provide early detection of tsunami arrival; very useful information for the issuance of tsunami warning.

The inter-sessional period was relatively active with much research conducted in the field of tsunami modeling and warning practice. Besides research conducted by KMA and in academic settings, The National Institute for Disaster Prevention(NIDP), established in 1997 in affiliation with Ministry of Government Administration and Home Affairs(MOGAHA), has made efforts to initiate research into earthquakes and tsunamis.

An NIDP report; “Evaluation of Tsunami Hazards along the Eastern Coast of Korean Peninsula” was published. In this report, the tsunami hazards along the eastern coast of Korea was evaluated by historical and hypothetical events. Information on tsunami occurring in this century in the East Sea was collected from the historical documents and local newspapers. Up until 1983, when the tsunami occurred, there wasn't a lot of interest in studying tsunami in Korea. However, interest grew in studying earthquakes and tsunami so that following the 1993 event tsunami survey teams were dispatched to the field and gathered detailed tsunami traces.

Using a numerical model, these two tsunami events were investigated. Their maximum elevations and arrival times were estimated, and characteristics of tsunami behaviors were understood. For the necessary prompt countermeasures, i.e., evacuation, and for the estimation of the risks by hypothetical tsunamis, we could compute the arrival time, tsunami height and duration of tsunami.

For the tsunami hazard mitigation along the eastern coast of Korea, a three-year research project was established in NIDP. This project aims at the exact estimation of tsunamis along the coast with the basis of understanding tsunami behaviors (non linear) in shallow water. The initial goal of the project is to estimate the exact arrival time and magnitude of tsunamis along the coast. The tsunami records, especially from the 1983 event, were already re-investigated through the field survey. And then, the tsunami run-up for Imwon port, which suffered the most severe damage in 1983, was computed using numerical models. The second phase of the research project, is to design an effective tsunami warning system for the Korean coast based on numerical simulations. In its third phase, a tsunami mitigation plan will be designed which includes construction in regards to structural coastal protection as well as education and training exercises.

In fact, the tsunami risk is relatively low in Korea when compared with meteorological disasters. However, the 1983 and 1993 tsunamis have stimulated our interest in a tsunami warning system. In addition, the ITSU-XVII and IUGG-IOC Joint Workshop provided us with more fruitful co-operation among relevant institutes and a motivation for research activity.

The projects being implemented will be completed in 2000, and then KMA will be in a better position to take an important role in the regional and international tsunami warning system.

MEXICO

Member Since: 1980
National Contact: Marco Polo Bernal-Yarahuan
Status in 1999: Unknown, no National Report received.

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NEW ZEALAND

Member Since: 1968
National Contact: Tom Finnimore
Status in 1999:

The Civil Defense in New Zealand is undergoing change from a principally response focused structure to an organization with the purpose of improving and promoting community resilience and continuity through comprehensive, integrated and risk-based emergency management. This will entail new legislation with new structures supporting and administering it. One major outcome will be for central government, a new Ministry for Emergency Management and for local government, a collection of Emergency Management Groups responsible for administering, managing and delivering the continuum – Risk, Reduction, Response and Recovery.

Concurrent with this restructuring however, mitigating against the tsunami effects by continuing awareness programmes; developing preventative inundation measures; updating and testing response plans and protocols remains unchanged. Continuing research in those coastal areas that are susceptible to a locally generated tsunami threat, is actively pursued throughout the wider civil defense community with support from both local government and central government agencies.

At ICG/ITSU-XVI, the Chairman expressed concern that the Cook Islands had not responded to his recommendation that the Islands have a national warning system. The New Zealand Delegate undertook to explore this issue with the Cook Islands.

The Cook Islands administration has been approached by Emergency Management and Civil Defense, New Zealand and confirms that a tsunami warning system is established within the islands. Further the Cook Islands have been encouraged to participate in ICG/ITSU business and to communicate with its Secretariat.

Some of the of mitigation measures that have been undertaken or are being conducted during the reporting period are:

- The Department of Earth Sciences, University of Waikato under Dr. Willem de Lange has been experimenting and researching the effects of artificial reefs along a portion of the Bay of Plenty coast, North Island New Zealand.
- Major seminars for emergency managers, utility managers, public information managers, emergency services, etc. of local government organizations have been held in both the North and South Island.
- A historical tsunami database has been compiled for New Zealand based on records back to 1820
- Work is progressing with the National Institute Water and Atmospheric Research (NIWA) establishing sea-level monitoring around the coast of both islands. Also being addressed, is for a recorder to be established at the Kermadecs, north of New Zealand, and on one of the sub-Antarctic islands to the south. These sites will provide a few hours warning of tsunamis generated at distant locations and will aid in the assessment of tsunami risk.
- The publication of pamphlets and associated material on threats from natural and other hazards is an on-going part of Public Awareness and Information supported by Emergency Management and Civil Defense. The awareness campaign covers schools, communities, government departments and agencies and the business sector.

The national warning system is used and tested regularly. The one system is used for passing warnings of all hazards. Whereas information is passed electronically and by phone/fax, manual checks by phone ring down are mandatory thus ensuring that the warning has been received.

Fifteen tsunami bulletins were received during the period. Of this number, three were Watch/Warning bulletins arising from the Balleny Island's earthquake of 25 March 1998.

Acting upon the information passed by the PTWC of this event together with New Zealand scientific advice, the Director, Emergency Management and Civil Defense issued a tsunami warning for all of the Southland Region coastal areas. The Balleny tsunami event, while small, has added useful information to our knowledge of the tsunami hazard in New Zealand, particularly from the Southern Ocean. It also highlighted both advantages and deficiencies in open-coast sea level monitoring in New Zealand. A recently established network of digital gauges has addressed these deficiencies by a strategic placement of recorders at open-coast or island sites.

Some Regional Councils with tsunami prone coastal areas have conducted major exercises in managing the effects of a tsunami event.

The International Tsunami Survey Team conducted the international investigation on the tsunami associated with an earthquake near the northwestern coast of Papua-New Guinea during early August 1998. The team of 13 researchers from Australia, Japan & the USA, included Dr. Willem de Lange from New Zealand. In his report, Dr. de Lange highlighted that there are significant physiographic similarities between that Papua-New Guinea coast and portions of the New Zealand coast.

New Zealand welcomed Dr. Chip McCreery, who on a flying official visit was a keynote speaker at two principal workshops held during late 1998. Emergency Management in New Zealand values Dr. McCreery's experience and knowledge. His visit, the first by a Geophysicist-in-charge from PTWC since Mr. Gordon Burton, further cemented relations between respective organizations. It should be noted that amongst his many talents, Dr. McCreery is a skilled trout fisherman!

At the ITSU Officers meeting in Jan. 1999, New Zealand offered to host ICG/ITSU-XVIII. This offer remains open for consideration at ICG/ITSU-VII.

NICARAGUA

Member Since: 1993
National Contact: Wilfried Strauch
Status in 1999:

The scientific organization responsible for building up and maintaining the seismic & mareographic monitoring systems & for developing the scientific studies necessary for the establishment of a tsunami warning system is the Instituto Nicaraguense de Estudios Territoriales (INETER), a governmental institution. The Nicaraguan Civil Defense is responsible for educating & informing the population as well as issuing a warning to those that could be affected by a tsunami.

The Nicaraguan seismic network, installed with funding from Sweden, Norway, Switzerland, Germany and the Nicaraguan government, has currently 26 telemetric stations (short-period vertical components) transmitting data in real time to the computerized data processing center at INETER Headquarters in Managua. There, 3 component sets of short-period, middle-period seismometers & accelerometers are installed.

A seismic broad band station (Quanterra data logger & STS-2 three component seismometer) is running as an autonomous station in the Nicaraguan mountain region. Data access is possible through high quality telephone links. The routine processing of seismic data is carried out on UNIX based workstations at Managua data center by qualified persons belonging to the Seismological Shift, operating 24 hours a day. The data of strong events are processed & a short report (hypocenter, magnitude, origin time, map) is printed within about 10 minutes after occurrence. Then, within a few minutes, this report is sent to a large number of institutions (Government, Civil Defense, mass media), using an automatic Fax server of the Nicaraguan telecommunications company. The Seismic Data Center receives messages from The Pacific Tsunami Warning Center and relays them to Civil Defense.

A network of about 13 digital accelerometer stations is installed in Managua & other towns along the Pacific Coast. INETER is working toward INTERNET access to these stations. Their data is important in determining the magnitude of strong seismic events.

Three digital tide gauge stations were installed off the Pacific coast of Nicaragua. The stations have local digital registration; remote access via telephone will be possible soon. Three more mareographic stations will be installed at the Atlantic coast, in 1999.

INETER is interested in cooperating with the international tsunami warning system; exchanging seismic & water level data in real or near real time. The institute would be able to maintain a digital sea level station linked via satellite to the headquarters of the Pacific Tsunami Warning System. Cooperating with neighboring countries as well as Colombia and Mexico, will be of great importance for an effective tsunami system. Direct access to selected seismic stations in theses countries is already possible. INETER will cooperate with German and US institutions to carry out geophysical and geological investigations of the Pacific Coast of Nicaragua in 1999&2000. One of the objectives is to investigate tsunami generation in the region.

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PERU

Member Since: 1972

National Contact: H.Soldi S. Status in 1999:

Peru carried out important activities in 1997 & 1998, to improve its warning system & disseminate information related to the occurrence of tsunamis along its coasts. These activities are described below.

Charts, designating areas capable of inundation, routes of escape, as well as emergency & temporal refuge zones, were printed in colour & distributed to the respective Port Captaincies. The areas of inundation were based on tsunami wave heights calculated for many points on the coast. These heights were determined using a) the Yamaguchi formula b) average peak (or top) high water & c) roughness. The heights were corrected for the effective existing slope. The arrival time of the initial wave was determined through a graphical method of wave refraction

The Directorate of Hydrography and Navigation of the Peruvian Navy (DHN) organized a training course on tsunamis numerical simulation in conjunction with the Department of Physics Oceanography of the Centro de Investigación Científica y de Educación Superior de Ensenada, Baja California, México (CICESE). Mr. Modesto Ortiz of CICESE gave the course, which was held at the DHN in Chucuito-Callao, Peru, from 31 August to 30 September 1998. The course, supported by the IOC, is part of the program, “Tsunami Inundation Modeling for Exchange” (TIME). Dr. Nobuo Shuto developed this method of numerical modeling near field tsunamis when he was at Tohoku University in Japan. The training program has resulted in a project to model 3 ports on the coast of Peru. This is a pilot project & if successful, by next year, coves & beach resorts will be covered.

TREMORS, a system that identifies tsunamis of distant origin, was installed in the DHN and the Instituto Geofísico del Perú (IGP) in October 1997. Mr. Francois Schindele could not carry out a demonstration regarding the operation of the TREMORS, because data from the Ñaña seismic station did not have the appropriate parameters in MINISEED format. In addition, the dedicated telephone line caused problems because the receiving system’s dedicated line between the IGP and the DHN, which is managed by Telefónica del Perú, failed. For this reason it was decided to change to a point to point digital circuit. This was operating on a trial basis, by October 1998. Meanwhile, the IGP made necessary changes in the sampling format in order to interface with the TREMORS programme. TREMORS requires a block of 512 bytes and 5 Hz bandwidth. This data is telemetered from the seismic station at Ñaña to Camacho, (headquarters of the IGP), and, then, is retransmitted to the DHN. Early this year TREMORS was setup and installed again, early in January, 1999. The IGP and DHN have developed a programming algorithm with the help of the Geophysics Laboratory (LDG) of France to optimize TREMORS parameters. Since this optimization, it has picked up several seismic events that have occurred in the world. A seminar on TREMORS was given in May 1999 in the IGP. DHN duty personnel were trained to operate the system.

The DHN and the Peruvian Corporation of Commercial Airports (CORPAC) hosted a course on communication using the Aeronautical Fixed Telecommunications Network (AFTN) system. The purpose of this course was to provide the users with IAT terminals, and training in operational procedures. Using this system, the interchange of messages is safe, regular, dynamic and efficient.. It also provides access to the data from aeronautical services.

Since October 1998, talks have been given in a broad range of educational and governmental institutions. Also, correspondents from El Comercio newspaper received talks on tsunami preparedness. Evacuation exercises continue at a national level. Also DHN has been preparing posters &brochures and intends to develop an audiovisual programme on tsunamis for the general population.

The DHN of the Peruvian Navy, working with the Hydrographic & Oceanographic Service of Chile (SHOA), designed a communication test for practice exercises in the exchange of information should both countries be threatened by a tsunami. So far, five communication exercises on warning/alert of tsunamis have been conducted between the two countries.

Plans are underway to incorporate data from a number of other coastal & oceanic water level stations, into Peru’s tsunami surveillance program. The proposed project, “Optimization of the Broadcasting & Assessment of ‘El Niño’ for Prevention and Mitigation of Disasters in Peru”, include the installation & allocation of nine coastal stations and four oceanic buoy stations. Data from these stations, which would be transmitted to the DHN in real-time, would be available for analysis when a tsunami is generated. A second proposed project, “Ocean-Atmosphere Surveillance System in the Southeast Pacific in Front of the Coast of Peru”, includes another three coastal water level stations and eight oceanic/coastal buoys for real-time data to be transmitted to the DHN.

A third project, “Integral Management of the Coastal Zones in the Southeast Pacific (Chile, Colombia, Ecuador, and Peru)”, has been proposed. Its purpose is to improve the integral understanding of our natural resources related to the different social economic activities in littoral areas. A primary goal is to establish a database managed by a Geographic Information System (GIS). Elements of the GIS would include, among others, information related to the zones capable of potential inundation in case of tsunamis, occurrence of populations involved in the inundation zones, and an inventory and location of health centers, firefighters, policemen, and other elements of the lifeline infrastructure. The proposed project would also suggest future population establishments and the organization of general plans, according to the vulnerability profiles that are recognized for extreme scenes as a tsunami and/or irregular surf of great intensity.

PHILIPPINES

Member Since: 1968
National Contact: Raymundo Punongbayan
Status in 1999:

In the Philippines, the Philippines Institute of Volcanology and Seismology (PHIVOLCS) is the lead agency in conducting tsunami risk mitigation studies. Delineation of tsunami impacted area is being undertaken or initiated based on tsunami reports, and field mapping is conducted whenever tsunamigenic earthquakes occur. Tsunami risk areas have also been identified.

Since it is not yet possible to issue warnings for local tsunamis, PHIVOLCS conducts active public information campaigns through lectures, seminars and publication of informative materials for the public, translated into different local dialects. The Institute also aims to enhance its earthquake research capabilities and will soon be a beneficiary of a JICA grant to improve its monitoring network.

During the times of large transPacific tsunamis the Pacific Tsunami Warning Center relays warning/advisory messages to PHIVOLCS. The messages are relayed through the Philippine Atmospheric, Geophysical and Astronomical Service Administration (PAGASA).

At this point PHIVOLCS is very interested to participate in all of the activities lined up by the organizing committee. In particular, we would like to join the Tsunami Inundation Modeling Exchange (TIME) project that will involve tsunami modeling. We are interested to acquire tsunami hazard mapping and modeling software from the said project.

RUSSIA

Member Since: 1968
National Contact: Igor P. Kuzminykh
Status in 1999:

As in previous periods, the Russian Federal Service for Hydrometeorology and Environmental Monitoring (ROSHYDROMET) is responsible for tsunami warnings and for the creation and functioning of the tsunami warning subsystem under the Russian Warnings and Actions in Emergency Situations System (RWAESS). ROSHYDROMET's Far Eastern Territorial Administrations for Hydrometeorology and Environmental Monitoring organize tsunami propagation observations, the calculation of estimated time of tsunami arriving at the coast of Russia, and the estimation of the degree of tsunami danger. They make decisions concerning issuing or canceling warnings against tsunami threat, form and transmit signals and messages to the units of RWAESS, as well as to the institutions of Ministry for Communications and Information and Local Administrations. Besides, they secure operative interaction with the Centers of the International Pacific Tsunami Warning System.

These functions are carried out by the Tsunami Warning Centers in Youzhno-Sakhalinsk, Petropavlovsk-Kamchatsky and Vladivostok, which are responsible for warnings about tsunamis in their administrative regions (Sakhalin and Kamchatka Provinces, Primorsky Land, accordingly).

The Geophysical Service of the Russian Academy of Sciences (GS RAS) secures continuous operative work of seismological stations, functioning within the framework of TWS and being at the same time a part of the Russian Federal Seismological Observation System. These stations locate submarine earthquakes, operatively determine their co-ordinates and estimate the degree of their tsunamigenity, immediately warn the subdivisions of RWAESS and local administrations about a tsunami threat in cases of very strong, close earthquakes, and transmit the data about the submarine earthquakes to the subdivisions of ROSHYDROMET.

At the present time, 5 seismological stations and 50 coastal hydrometeorological stations, carrying out visual sea level observations, participate in the National Tsunami Warning Service. The gauge sites, which were destroyed during the 1994 Shikotan earthquake and tsunami haven't been restored yet.

As in previous periods of operation, the TWS is based on seismological method for short-term tsunami forecasting. The magnitude-geographical criterion is used for the estimation of the potential threat according to seismological data. Hydrophysical (level) observations, being of secondary significance, are also, in certain cases, important for short-range tsunami forecasting for the adjacent coastal regions.

The information exchange between regional TW Centers within Russia and the Centers in other countries is carried out, as before, through the WMO GTS channels.

During 1997, 1998 and the first half of the 1999, 111 earthquakes with magnitudes M>6 were registered by ss Petropavlovsk and 116 by ss Youzhno-Sakhalinsk. Tsunami warnings were issued in three cases. On 5 December 1997, an earthquake occurred in the Kronotsky Bay, near the coast of Kamchatka (M = 7.5, lat. = 55.5 deg. N, long. = 63.3 deg. E). Independently from each other ss Petropavlovsk and ss Severo-Kurilsk announced about a tsunami threat: over Kamchatka Province and Severo-Kurilsk, accordingly. Coastal hydrometeorological stations hadn't registered any tsunami, but by visual inspection from a helicopter in the Kronotsky Bay, a tsunami from 0,5 to 1,0 meter was revealed.

On 8 March 1999, a warning about the tsunami threat in Severo-Kurilsk was issued (M=6.6, lat = 52 deg. N, long = 159.8 deg. E). The alarm turned out to be false.

In 1997-99, Russian TW Centers regularly exchanged messages with the Centers in Hawaii, Tokyo, Hong Kong, Palmer (with the latter - from August 1998). During 1998-1999, delays in transmissions of messages through the GTS channels decreased considerably. The following table shows average travel time for messages to Petropavlovsk from Tsunami Warning Centers in Pacific Region.

TW Centers	1997	1998	1999
Hawaii	**34 min**	**12 min**	**26 min**
Tokyo	**50 min**	**5 min**	**2 min**
Hong-Kong	**29 min**	**7 min**	**7 min**
Palmer	**-**	**12 min**	**8 min**

In 1998, the Tsunami Warning Center in Youzhno-Sakhalinsk was connected to the Internet and was included in the information dissemination e-mail addresses lists at Pacific Tsunami Warning Center and Alaska Tsunami Warning Center. Messages come to the Youzhno-Sakhalinsk Center by e-mail simultaneously or somewhat faster than by the GTS.

In 1999, work is underway toward the installation of two automated tide gauges in Kamchatka and the Kuril Islands. The equipment is being supplied by Pacific Region of National Weather Service of the USA, owing to financial support from the Intergovernmental Oceanographic Commission. In May 1999, two Russian experts from Petropavlovsk, Kamchatsky and Youzhno, Sakhalinsk attended special courses at the PTWC, under the Visiting Experts Programme. They were instructed in the installation and maintenance of the tide gauges. They returned to Russia in June 1999 bringing with them part of the equipment.

Utilizing the geostationary satellite GMS-5 for the collection of data from these tide gauges has already been agreed with the Japan Meteorological Agency.

Two new Federal Programmes to restore and develop national tsunami warning service have been confirmed and launched in Russia. According to FP, "The Development of Federal Seismological Observations and Earthquakes Forecasting System “, since 1997, work has been underway to create in Sakhalin and Kamchatka automated complex seismological observation sites equipped with automatic seismostations and telemetric apparatus of various types: analog and digital. Four digital automatic seismostations (including 3 broadband and 3 short-period seismometers each) will be installed on the Sakhalin Island.

Besides, at four stations on Kuril Islands digital seismometers TS-1(2) are installed within the framework of MS programme. They will be connected to the Internet and secure real-time operation.

Two local seismological systems equipped with digital and analog telemetric devices are being developed in Kamchatka.

In 1999, work began on the project "Securing stable functioning and further development of the National Tsunami Warning SYSTEM” under the Federal Programme "World Ocean”. According to the project, the hydrometeorological stations are to be additionally equipped with remote tide gauges for revealing tsunamis, transmitting data over various communication channels (surface and satellite). The project also foresees that regional data collection and processing centers, data and messaging exchange communication systems should be considerably modernized. The project is to be realized in two stages: 1999-2001 and 2002-2007.

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Status in 1999:

The US has continued to operate the Pacific Tsunami Warning Center (PTWC) in Ewa Beach, Hawaii, and the West Coast/Alaska Tsunami Warning Center (WC/ATWC) in Palmer, Alaska, since ICG/ITSU-XVI in September 1997. The more significant developments that have occurred during the period since the Sixteenth Session include: expansion of the Pacific Satellite Sea Level Network and the use of Internet by the U.S. Tsunami Warning Centers to collect Pacific wide seismic data.

The NWS Pacific Region continues to support the Activities of the Computing Center, Novosibirsk, in the development of the Historical Tsunami Database. US development of the

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DOS based version has been completed and distributed to the emergency managers for their evaluation and suggestions. The development of a Windows based system is continuing.

The NWS Pacific Region continues to work with PEACESAT on a variety of activities related to the TWS. The first of these is making the data on EMWIN also available on PEACESAT, which is targeted to occur in 2000. The second is a cooperative effort that we are developing with IRIS to use a dedicated data channel on PEACESAT to bring back Western Pacific seismic data in real time from 6-8 stations.

With the approval given in Lima at ITSU-XVI, PTWC implemented a change in its procedures in early 1998 to issue regional Watch and Warning Bulletins for all Pacific earthquakes with magnitudes greater than 7.5. PTWC has incorporated a TREMORS system to measure seismic moment from the Kipapa station broadband seismic data, to calculate magnitudes more meaningful to forecasting tsunami generation.

The PTWC continues to improve its information technology infrastructure. A completely redundant system of main operational computers is now in place. Hawaii earthquakes are now automatically located within about two minutes by two independent software systems, and can also be located by a third interactive method. Teleseisms can be located by either of two independent interactive methods. Earthquake magnitudes can also be measured with automatic routines or interactively.

Over the past two years, the PTWC has made several improvements to its seismic data processing capabilities to improve the performance of the center. A new graphical interface has been written to permit watchstanders to rapidly pick first arrivals for either teleseismic or local earthquakes and then automatically pass those data to location routines. The PTWC interface to the US National Earthquake Information Center (NEIC) for retrieving hypocenter and pick data has been automated, activating whenever a seismic alarm is triggered.

A small seismic project also continues to progress at PTWC. A prototype low cost single component seismic station that can detect P-waves from both local and teleseismic sources and transmit these detections via satellite immediately back to PTWC has, for the last two years, been operating in a test and development mode at PTWC. The first deployment is planned for Pago Pago, American Samoa later this year.

Two major enhancements to the Pacific array of gauges are currently underway. 1) Chile's SHOA recently purchased equipment, through an agreement with the US, for an additional ten gauges for deployment along their coast and offshore islands. PTWC provided training to SHOA personnel regarding the installation and maintenance of those gauges. Several have already been installed at the time of this writing. 2) The Russian Federation, in a cooperative project with the US and the IOC, has purchased 3 new gauges for their Pacific coasts. Two of the gauges are scheduled for installation this summer at Severo-Kurilsk and Ust-Kamchatsk.

A new, very practical, and effective method for receiving bulletins is via the Emergency Managers Weather Information Network (EMWIN). EMWIN can be used anywhere within the GOES footprint in the eastern and central Pacific. Using EMWIN software, Tsunami Warnings can be alarmed to make a sound or even dial a phone or send a page. Tsunami Bulletins are already being carried by EMWIN, and graphical products such as travel time maps are planned.

Within the past year and in cooperation with the USGS, the WC/ATWC has implemented an Earthworm system, which permits raw data exchange among various agencies and centers. This system provides the WC/ATWC the ability to receive/transmit digital seismic data with others who have an Earthworm system. To date, approximately 60 channels of seismic data are recorded and processed at the WC/ATWC.

The PMEL Tsunami Program seeks to mitigate tsunami hazards in Hawaii, California, Oregon, Washington, and Alaska through research aimed at improving operational products. A major part of the FY1998 work performed went toward the National Tsunami Hazard Mitigation Program (NTHMP). As the lead organization of the nation for implementation of the NTHMP, the PMEL Tsunami Program coordinated three Federal agencies and five states participating in the NTHMP.

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Development continued on Deep ocean Assessment and Reporting of Tsunamis (DART) buoys to detect tsunamis in the open ocean and report their wave heights in real-time. Prototype DART buoys were deployed in the northern Gulf of Alaska and at Station P (50N, 145W).

Development continued on the Method of Splitting Tsunami (MOST) model, with the goal of providing the Pacific Disaster Center (PDC) with the capability to make real-time forecast of tsunami wave heights during Pacific tsunamis. Sensitivity analyses of MOST simulations were started to determine the tsunami source variables that need to be estimated immediately after a tsunamigenic earthquake in order to obtain an accurate forecast of tsunami wave heights. The recently established Center for Tsunami Inundation Mapping Efforts (TIME), associated with PMEL, provided valuable assistance to inundation modeling efforts in Oregon, resulting in a tsunami hazard map of the Seaside-Gearhart Area. During the past 3 years, progress has been made in each of the following areas:

1. Coordination - NOAA's Emergency Managers Information Network (EMWIN) is being tested at Grays Harbor, Washington as a way to alert coastal communities about small (less than Ms 5.5) earthquakes.
2. Tsunami Detection Buoys - A third generation prototype buoy was successfully deployed in May 1999, near Monterey, California, to provide real-time deep ocean tsunami observations to an accuracy of 1 centimeter. Deployment of a four-buoy system is scheduled for September 1999.
3. Inundation maps - All five states involved in the tsunami mitigation effort are engaged in producing/upgrading tsunami inundation maps.
4. Mitigation - A strategic plan for implementing tsunami mitigation projects was developed and published for use in guiding mitigation product development. A 10-minute video describing the 1993 Sea of Japan tsunami and tsunami safety tips was produced. In Oregon, communities were involved in the development and printing of tsunami evacuation brochures.

In Washington, a State/Local Tsunami Workgroup, consisting of coastal counties' emergency managers and state agencies, was formed. Tsunami warning and evacuation signs were placed up and down the coast of Washington. Further, tsunami interpretive signs were placed in 29 highly visited locations by February 26, 1999. Tsunami web sites have also been developed in all coastal counties. A tsunami annotated bibliography and directory has been developed and given to emergency management personnel and various library systems. A TsuInfo Alert Newsletter is being sent monthly to all five tsunami states and designated parties.

Scientists working at National Geophysical Data Center (NGDC) with support from the National Science Foundation are preparing a catalog of global tsunamis for 1983 through 1999 updating the Soloviev, et al., final Pacific Tsunami Catalog, 1969-1982 to the end of the millennium. The catalog will be published early in the year 2000. The Center also has completed a history of 98 tsunamis and their effects, occurring in the Caribbean, which has been accepted for publication by Natural Hazards Journal. The staff is preparing a revised and updated catalog of Tsunamis Affecting the United States, 1690-1988, through to the year 2000. They have data on 484 events, which updates the earlier version (1989) which had 418 events.

A slide set of the Shikotan, Kuril Islands Earthquake and Tsunami, October 4, 1994, was produced by the NGDC during the intersessional period. These photos and much of the information in the slide set is from the publication entitled “Geodynamics of Tectonosphere of the Pacific Eurasia Conjunction Zone”, Russian Academy of Sciences, Far East Branch, Institute of Marine Geology and Geophysics, Yuzhno-Sakhalinsk, 1997. A slide set of the Papua New Guinea Tsunami, July 17, 1999, is under development. Photos have been supplied by Humboldt State University and by the National Mapping Bureau of Papua New Guinea.

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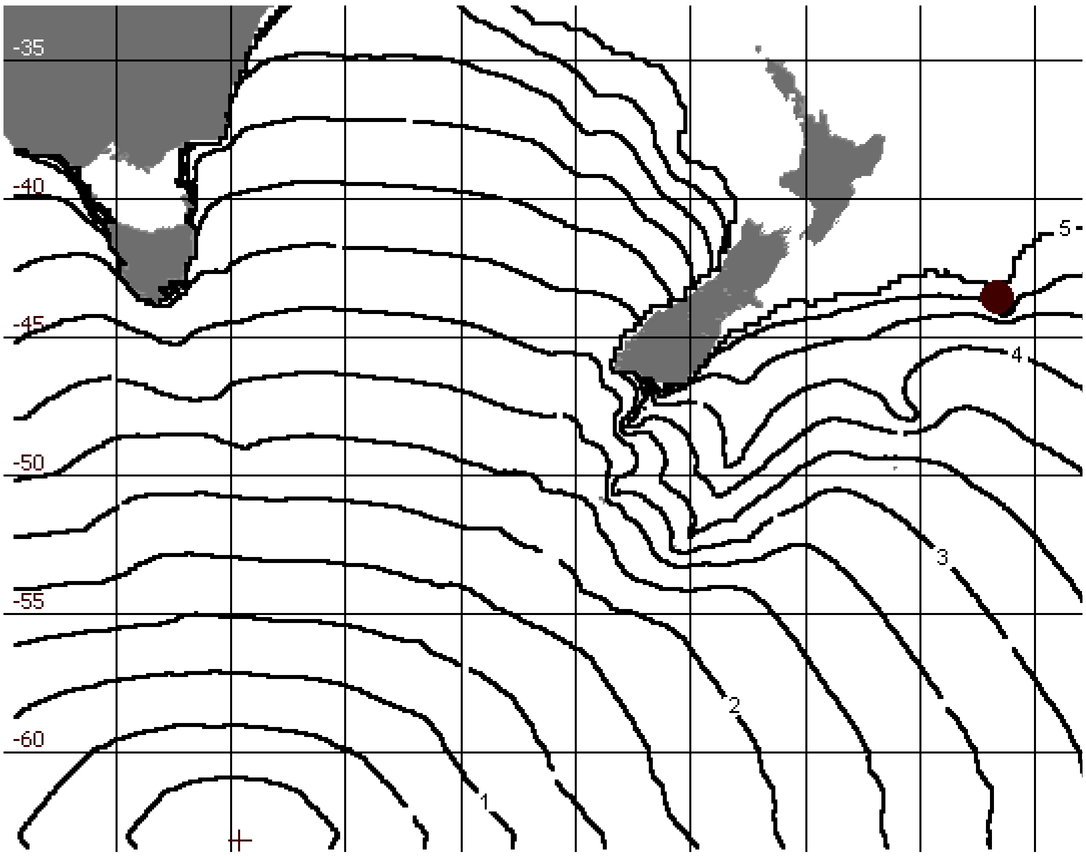
EARTHQUAKE REPORT—Bellany Earthquake, 25 March 1998



COMMENTS

The Balleny Sea earthquake is considered to be the largest oceanic intraplate earthquake ever detected. The event occurred near, but distinctly separate from, the boundary between the Antarctic and Australia-India tectonic plates. The boundary may be characterized as a set of interconnecting, east-west trending spreading centers and north-south trending transform faults. Surprisingly, the main shock epicenter and CMT location, as well as the pattern of aftershocks, trend in an east-west direction rather than in a north-south direction, subparallel to the trends of the fracture zones emanating from the transform faults. This continues to be a topic of discussion among seismologists and tectonophysicists.

Since the earthquake occurred in or near a regime of mostly horizontal fault motion and far away from populated areas, a significant tsunami was not expected to develop. Nevertheless, acting on the side of safety, the PTWC kept its regional warning/watch process in effect until they received confirmation from their nearest telemetered water level gauge that there was no tsunami. This gauge, located in the Chatham Islands of New Zealand, would have recorded an initial tsunami wave at about 0823Z and transmitted that data to the Center at 0853Z.

The PTWC cancelled it regional warning/watch process at 0900Z.One may have noticed that some localities in the southwest Pacific region were missing from the list of places eventually receiving warnings or watches. Australia, Tonga, Vanuatu, and the Solomon Islands, all independent entities, are examples. The last three of these examples have no formal means of receiving the PTWC messages at this time. ITSU and the PTWC are working on ways to reach all the Pacific nations with the PTWC messages and to make sure all receive warnings or watches when appropriate.

EARTHQUAKE REPORT—Bellany Earthquake, 25 March 1998, con't

PTWC ACTION CHRONOLOGY

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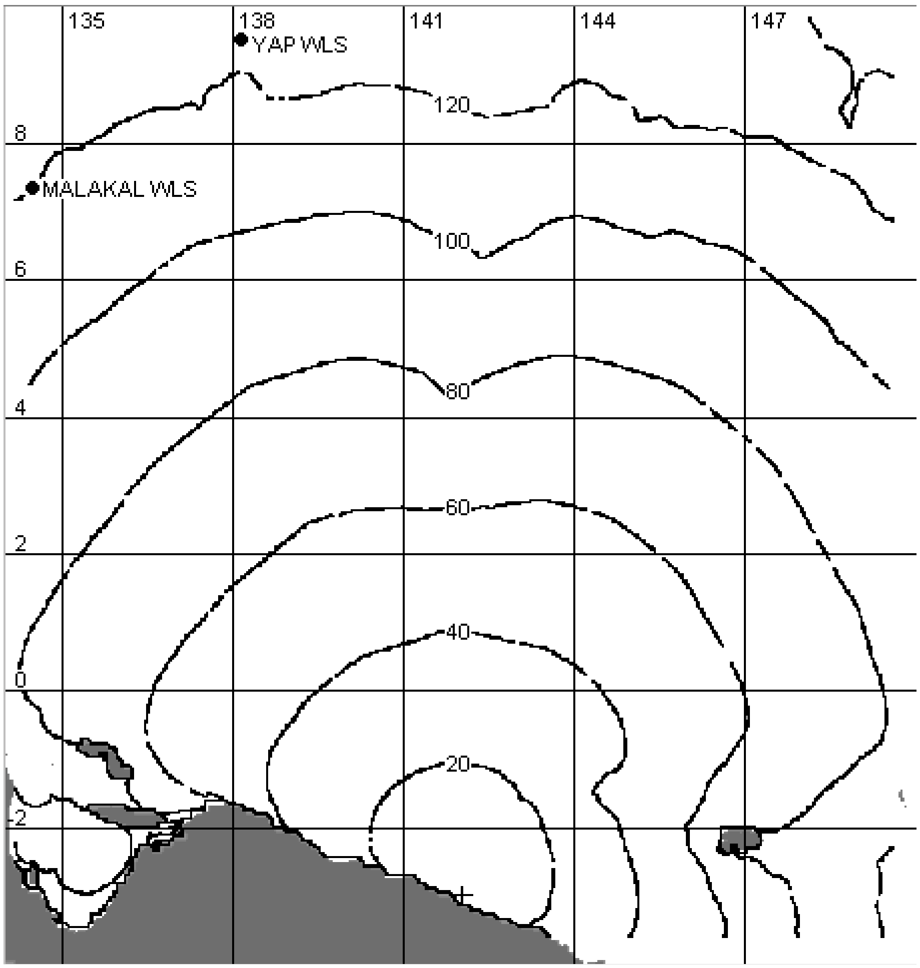
Alarms:            Preliminary Earthquake Parameters for Regional
 HON lp (long period) -   0335Z  Warning/Watch (RWW) Message:
 Alaska -   0335Z   origin time - 0313Z    latitude   63.2S
 Mainland - 0339Z   vicinity - Balleny Is. longitude 150.3E
                    magnitude - Ms 8.1
Messages:
RWW#1 - 0445Z Initial message: places warned - 0, places in watch - 7
RWW#2 - 0536Z 1st supplement: places warned - 0, places in watch - 7
RWW#3 - 0655Z 2nd supplement: places warned - 1, places in watch - 6
RWW#4 - 0749Z 3rd supplement: places warned - 3, places in watch - 5
RWW#5 - 0900Z Final supplement - cancellation
Places warned, action taken:
New Zealand - no evacuation on advice of local tsunami advisor
New Caledonia - unknown
Cook Islands - unknown
Places in watch:
American Samoa, Fiji, Samoa, French Polynesia, Nauru
```

HARVARD SOLUTION

```
March 25, BALLENY ISLANDS REGION, Mw=8.2
Natasha Maternovskaya
Goran Ekstrom
CENTROID, MOMENT TENSOR SOLUTION
HARVARD EVENT-FILE NAME M032598C             ########---
DATA USED: GSN                           ##########---------
MANTLE WAVES:    37S, 95C, T=200       ##########-------------
CENTROID LOCATION:                   ############----------   --
ORIGIN TIME        3:13: 7.4 0.3    ###########------------ P ---
LAT 62.95S 0.02;LON 147.72E 0.05   ###########-------------   ----
DEP  28.9 1.9;HALF-DURATION 26.5   ###########--------------------
MOMENT TENSOR; SCALE 10**28 D-CM  ###########----------------------
  MRR=-0.68 0.03; MTT= 0.97 0.02  ----#######----------------------
  MFF=-0.28 0.02; MRT=-0.71 0.17  -----------#---------------------
  MRF=-0.15 0.17; MTF= 1.45 0.01  ----------#######################
 PRINCIPAL AXES:                   ---------######################
 1.(T) VAL=  2.09;PLG=14;AZM=148   ---------######################
 2.(N)      -0.72;    60;    263    --------#####################
 3.(P)      -1.37;    26;     51     --------############   ####
BEST DOUBLE COUPLE:M0=1.7*10**28       ------############ T ##
 NP1:STRIKE=192;DIP=62;SLIP=-171         -----###########
 NP2:        97;    82;      -29             --#########
```

PAPUA NEW GUINEA EARTHQUAKE AND TSUNAMI — 17 July 1998



PAPUA NEW GUINEA EARTHQUAKE AND TSUNAMI

On July 17, 1998 an earthquake (MS 5.8) struck the north coast of the Island of New Guinea in Papua New Guinea at 5:49pm local time (08:49 GCT). The earthquake was felt strongly by villagers situated on the narrow strands separating Sissano Lagoon from the ocean to the north. For many of these villagers it would be the next to the last sensation of the powerful forces of nature. Within minutes a great tsunami swept over the strands carrying thousands of people to their deaths. This tsunami would prove to be the most devastating, in terms of loss of life, of a decade locally destructive tsunamis.

Meanwhile the seismic waves of that original earthquake were just reaching the alarms of the Pacific Tsunami Warning System's (ITSU's) operational center in Hawaii. The Pacific Tsunami Warning Center (PTWC) promptly located the earthquake and, because its magnitude was less than the threshold for issuing a Regional Warning and Watch, it issued a Tsunami Information Bulletin to the participants in ITSU alerting them that a major earthquake had occurred in Papua New Guinea and that any tsunami generated by the earthquake would not be destructive in the far field away from the source of the earthquake.

Soon after its message was issued the PTWC began to receive enquiries about the possibility of a tsunami near the source. The Center reported that it observed some indications of a small tsunami at its nearest water level stations in Palau and in Yap, FSM, to the north of Papua New Guinea, but nothing of significance elsewhere in its network of telemetered water level stations. The tsunami, while locally very large on the north coast of the Island of New Guinea, died out quickly as it spread away from the coastal area .

This event has focused attention on two elements necessary for any effective tsunami warning system. They are the need to identify the scope of the local tsunami hazard, and the need for local, or at least regional, tsunami warning systems.

Since the occurrence of the event in Papua New Guinea evidence gathered seems to indicate that the primary cause of so great a tsunami from a relatively small earthquake is the coseismic slumping of a large area of the seafloor immediately offshore from the Sissano Lagoon. Slumping has been a factor in many destructive tsunamis and may be the major factor in most the tsunamis in the Mediterranean Sea. About half the lives lost to tsunami in the Great Alaska Earthquake of 1964 were lost to tsunamis caused by slumping, not to the tectonically generated tsunami. Since the Papua New Guinea event there has been a renewed interest in evaluating the potential for submarine slumping off coasts of many heavily populated areas both in the Pacific and elsewhere. This is good because it not only helps to identify areas of increased tsunami hazard but it also helps to raise the public's awareness of the tsunami hazard in general.

The second element, the need for local or regional warning systems, was indeed brought to bear in the Papua New Guinea event. It would have been nearly impossible even for a local warning system to issue an effective warning in time for those in danger to evacuate the areas inundated but there's more to warning systems than just a warning center. A warning system entails an ongoing program of heightening public awareness of the hazard, fostering studies of the local hazard, and developing a plan to mitigate the effects of this hazard. Since the event the International Tsunami Information Center (ITIC) has sent thousands of its booklet, "Tsunami, the Great Waves", to officials in Papua New Guinea and plans to send more in the near future. These are being distributed to residents of tsunami prone areas in the country. Hopefully this will be the beginning of an ongoing program in that country that will significantly reduce losses to tsunami in the future.

We will not go into the details of the Papua New Guinea event here because so much has been written and described elsewhere. Please consult the articles in the reading list that follows this section. If you have problems obtaining copies of articles of interest, contact the ITIC and they will attempt to obtain the articles for you. (MB)

PAPUA NEW GUINEA TSUNAMI REPORT

Materials at ITIC on the 17 July 1998 Tsunami in Papua New Guinea

Davies, Hugh, 1999, Aitape 1998 Tsunami: Report on the visit of the expert team to the survivor villages 16-19 September 1999 and Report on the Tsunami Science meeting 19-20 Sep 1999, e-mail from hdavies@upng.ac.pg to Tsunami Bulletin Board, October 7, 1999. 10 pages.

---, 1999, Tsunami PNG 1998: Extracts from Earth Talk: Port Moresby, PNG, Graphos Art Ltd., 49 p.

The first edition entitled "The Sissano Tsunami 1998" was a limited edition published by the University of Papua New Guinea Printery in January 1999. Both editions comprise extracts from Earth Talk, a weekly column in the National Newspaper, Port Moresby. The second edition incorporates additional text and illustrations.

De Lange, Willem, 1999, 17 July 1998 Saundaun Tsunami: Tephra, October 1999, p. 42-50.

Goldsmith, Peter, Alastair Barnett, James Goff, and others, 1999, Report of the New Zealand Reconnaissance Team to the area of the 17 July 1998 Tsunami at Sissano Lagoon, Papua New Guinea: Bulletin of the New Zealand Society for Earthquake Engineering, v. 32, no. 2, p. 102-118.

Imamura, Fumihiko, 1998, Sissano Tsunami in Papua New Guinea, July 1998: Incede Newsletter, v. 7, no. 2, p. 1-3.

Kawata, Yoshiaki, 1999, Field survey on the 1998 tsunami in the northwestern area of Papua New Guinea: Japan, Research Center for Disaster Reduction Systems, 81 p., illus. Grant-in-aid for Scientific Research (B) (1), Ministry of Education, Science, Sports and Culture, Japan. Matsuyama, Matsufumi,

McSaveny, Mauri,1999, Tsunami, the experience: Tephra, October 1999, p. 36-41.

Ripper, I. D., and Letz, H., 1999, The Sissano Lagoon (Aitape) Tsunami: Which earthquake was responsible?: Port Moresby, Papua New Guinea, Department of Mineral Resources, Geological Survey, Papua New Guinea Geological Survey, 19 p.

Tanioka, Yuichiro, 1999, Analysis of the far-field tsunamis generated by the 1998 Papua New Guinea Earthquake: Geophysical Research Letters, v. 26, no. 22, p. 3393-3396.

Tappin, D., 1999, Tsunami! Offshore surveys after the Papua New Guinea Event of July 1998: SOPAC Projects, v. 13, p. 1-12 . South Pacific Applied Geoscience Commission (SOPAC).

Tappin, David R., Matsumoto, Takeshi, Watts, Phil, and others, 1999, Sediment slump likely caused 1998 Papua New Guinea Tsunami: Eos, Transactions of the American Geophysical Union, v. 80, no. 30, p. 1+.

Taylor, Paul R.P., D.L. Emonson, and J.E. Schlimmer, 1998, Operation Shaddock--the Australian Defence Force responds to the tsunami disaster in Papua New Guinea: Medical Journal of Australia, v. 169, p. 602-606.

PAPUA NEW GUINEA TSUNAMI REPORT

Materials at ITIC on the 17 July 1998 Tsunami in Papua New Guinea, con't

Tsunami victims rebuilding their lives:Aid worker,1999, Pacific Islands Monthly, August, p. 29.

Walsh, J. P., and Yeh, Harry, 1999, The effect of bathymetry on tsunami characteristics at Sisano Lagoon, Papua New Guinea: Geophysical Research Letters, v. 26, no. 23, p. 3513-3516.

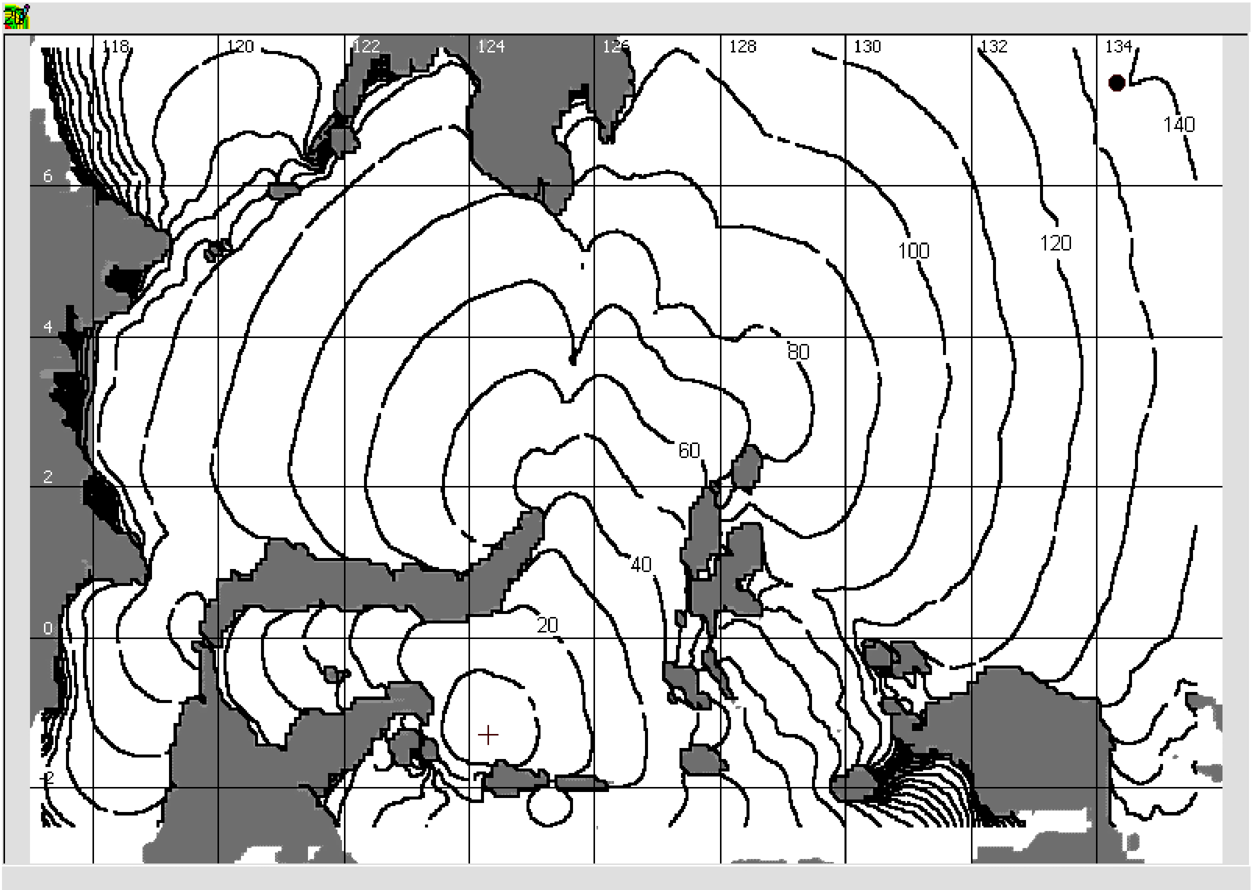
E-TEXTS:

National Oceanographic and Atmospheric Administration. 17 July 1998 Papua New Guinea Earthquake and Tsunami Web-Link Compilation. http://www.pmel.noaa.gov/~tsunami/PNG/

Tohoku University, Sendai, Japan. Preliminary report on the tsunami caused by Sissano the Earthquake at West Sepik, PNG on 17 July 1998 http://www.tsunami.civil.tohoku.ac.jp/hokusai2/topics/tsunami-news/PNG/PNG2.html or http://www.tsunami.civil.tohoku.ac.jp/hokusai2/topics/tsunami-news/PNG/PNG-pre/pre-rprt1.html

AGU WESTERN GEOPHYSICS MEETING ABSTRACTS (June 27-30,2000, Tokyo) Abstracts can be searched for papers dealing with the Papua New Guinea Tsunami Earthquake. at URL: http://agu.org/meetings/waiswp00.html

EARTHQUAKE REPORT—South Molucca Sea, 25 November 1998



Hypothetical tsunami travel times from the preliminary epicenter determined by the PTWC. Isochrones are at 10-minute intervals. Nearest telemetered water level station- Malakal, Belau- located at dot in upper right corner of figure. [Tsunami travel time calculations and graphics based on software developed by the Russian Academy of Sciences, Siberian Division's Institute of Computational Mathematics and Mathematical Geophysics]

COMMENTS

The Molucca Sea earthquake occurred at the southern end of a seismically active structure that runs northward the length of the Molucca Sea. The mechanism of the earthquake, as indicated by the Harvard CMT solution, tends to be lateral in nature, although there is a somewhat significant component of dip slip motion. Given the location and probable nature of faulting, it is unlikly that a tsunami would have been generated by this quake that could cause flooding or damage in the main Pacific basin. Since there was the possibility of a local tsunami in the Molucca Sea, Indonesia was queried by facsimile shortly after the event. The response from Indonesia was that no tsunami had been reported. Meanwhile in Guam the Emergency Services Office initiated the first known evacuation of its coastlines in recent times. No tsunami was observed in Guam.

Again in this event, as was the case with the Balleny Sea earthquake, there appear to be some inconsistancies regarding whom receives and who does not receive warning/watch messages. The PTWC recognizes this and is working to provide uniform coverage for its messages in its area of responsibility.

EARTHQUAKE REPORT—South Molucca Sea, 25 November 1998, con't

PTWC ACTION

```
Alarm: HON lp (long period) – 1423Z
Parameters for RWW Messages:
     Determined at: 1447Z
     Origin time – 1410Z
     Vicinity – S. Molucca Sea
     Latitude -    1.3S
     Longitude – 124.3E
     Magnitude – Ms 7.6
Messages:
        RWW#1 – 1507Z     Initial places warned – 3, places in watch – 7;
        RWW#2 – 1607Z     1st Supplement
                places warned – 6,
                places in watch – 6
        RWW#3 – 1707Z Cancellation
```

PLACES WARNED; ACTION TAKEN:

Belau – Weather Service Office (WSO) received warning & informed NEMO
Yap – WSO received warning; no indication of further action
Philippines – PHIVOLCS informed field stations in southern Philippines
Guam – Emergency Services Office evacuated low-lying areas.
Taiwan – CWB informed CAA, Tao Yuan Oil Rfnry, Navy Wea, Nuc Plant Org
Japan – issued "tsunami attention" for Japan Pacific coast

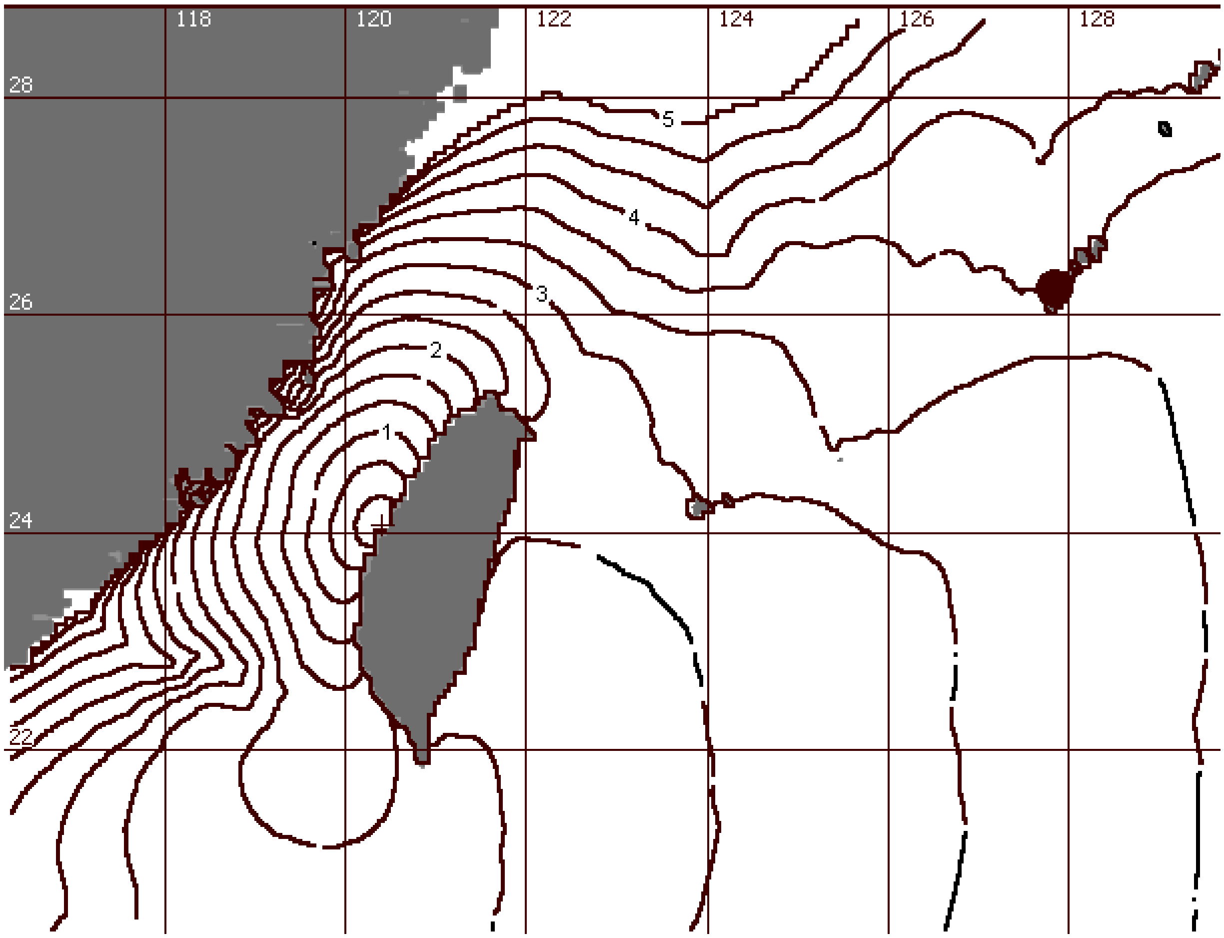
PLACES IN WATCH:

Chuuk, Minamitori-shima (Marcus I.), Marshall Is., Wake I., Russia, Nauru

HARVARD SOLUTION

```
November 29, SOUTHERN MOLUCCA SEA, Mw=7.7
CENTROID, MOMENT TENSOR SOLUTION
Mike Antolik
HARVARD EVENT-FILE NAME C112998A
DATA USED: GSN                                    #########--
L.P. BODY WAVES: 16S, 43C, T= 45                ##########-------
MANTLE WAVES:    16S, 43C, T=135            # T ########-----------
CENTROID LOCATION:                        ###   #######--------------
ORIGIN TIME:      14:10:45.9 0.2         #############---------   ----
LAT  2.02S 0.02;LON 124.87E 0.02        ##############--------- P -----
DEP  21.2 1.4;HALF-DURATION 18.8        #############----------   -----
MOMENT TENSOR; SCALE 10**27 D-CM       #############--------------------
    MRR=-1.02 0.06; MTT= 1.66 0.05     -############--------------------
  MFF=-0.63 0.05; MRT=-0.76 0.14       ---#########--------------------
  MRF= 1.67 0.21; MTF= 3.17 0.05       ------######-------------------##
 PRINCIPAL AXES:                        -----------#------------######
 1.(T) VAL=  3.91;PLG= 4;AZM=324        -----------####################
 2.(N)       0.06;    58;    227          --------####################
 3.(P)      -3.97;    32;     56          --------###################
BEST DOUBLE COUPLE:M0=3.9*10**27            -------################
NP1:STRIKE= 95;DIP=65;SLIP= -20              -----##############
 NP2:       194;    72;     -153                  -##########
```

TAIWAN EARTHQUAKE REPORT— 20 SEPTEMBER 1999



COMMENTS

The initial PTWC epicenter for the Taiwan earthquake, while on land, was sufficiently near the coast to warrant the issuance of a regional tsunami warning/watch message. Subsequent locations moved the epicenter westward eventually to about the middle of the island. This fact, together with no reports of a tsunami from Taiwan and no tsunami observed on the Naha, Okinawa, tide gauge, which is telemetered to the PTWC in near real time, led to a cancelletion of the RWW after only 2 messages were issued.

Tectonically, Taiwan appears to be a wedge uplifted between opposed subduction regimes. North-south trending faults in the western part of the island tend to dip eastward and may be an extension of the Luzon thrust system to the south. Along the eastern side of the island the north-south trending faults tend to dip westward. Thus Taiwan can be characterized as a kind of micro-plate between the Eurasian and Philippine Sea tectonic plates. The western fault system is considered to be much more active than the eastern system. Even though there was considerable surface rupture along the western fault system, the deformation associated with the rupture was insufficient to generate a tsunami in the Taiwan Strait. Nevertheless, a hypothetical tsunami travel time chart is presented to illustrate the amount of time available for evacuation had a tsunami been generated.

TAIWAN EARTHQUAKE REPORT— 20 SEPTEMBER 1999, con’t

PTWC ACTION CHRONOLOGY

```
Alarm:  HON lp (long period) – 1759Z
Warning/Watch (RWW) Messages:
        origin time – 1748Z
    vicinity – Taiwan
    latitude   23.8N
    longitude 121.3E
    magnitude – Ms 7.6

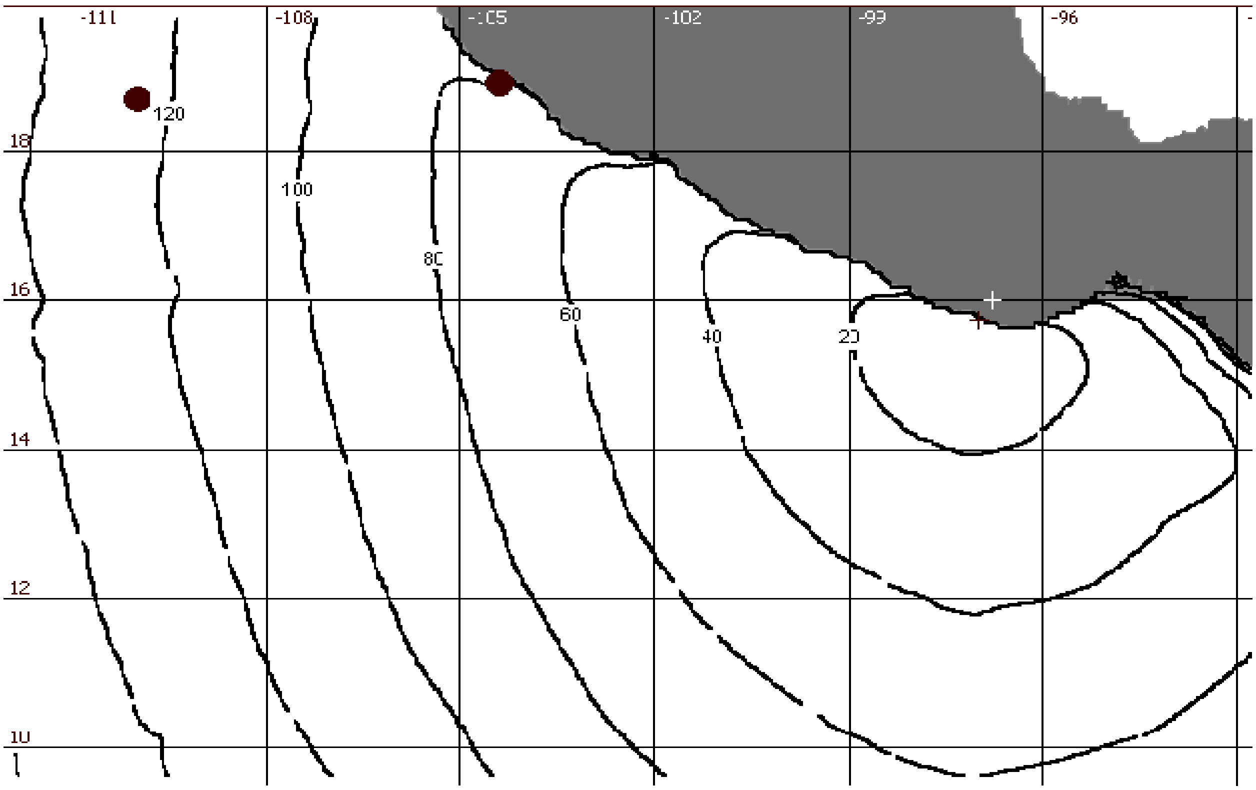
Messages:
RWW#1 – 1830Z Initial message: places warned – 6, places in watch – 6
RWW#2 – 1929Z 1st supplement: places warned – 8, places in watch – 6
RWW#3 – 2015Z Final supplement: cancellation

Places warned, action taken:
Taiwan – unknown
Japan – unknown
Philippines – unknown
Belau – unknown
Yap – unknown
Guam – unknown
Minamitori-shima (Marcus I.) – unknown
Russia – unknown
Places in watch:
Chuuk, Marshall Is., Hong Kong, Wake I., Nauru, Midway I.
//////////////////////////////////////////////////////////////////////////
HARVARD SOLUTION
September 20, TAIWAN, Mw=7.7
(Natasha Maternovskaya & Erik Larson)
CENTROID, MOMENT TENSOR SOLUTION
HARVARD EVENT-FILE NAME C092099A
DATA USED: GSN                               -----------
L.P. BODY WAVES:  4S, 12C, T= 45         ------------------#
MANTLE WAVES:     4S,  7C, T=135       -----------------####--
CENTROID LOCATION:                   ----------------#########--
ORIGIN TIME:      17:47:38.2 0.3    -   -----------###########---
LAT 23.94N 0.02;LON 120.71E 0.06   -- P ---------##############---
DEP  20.7 1.3;HALF-DURATION 18.8   --   -------################---
MOMENT TENSOR; SCALE 10**27 D-CM  ------------#################----
  MRR=-3.37 0.08; MTT=-0.93 0.07  -----------##################----
  MFF=-2.44 0.12; MRT=-1.54 0.18  ----------########   ########----
  MRF=-1.98 0.20; MTF=-1.33 0.05  ---------######### T ########----
 PRINCIPAL AXES:                   -------##########   #######----
 1.(T) VAL=  4.22;PLG=71;AZM=133   -------###################-----
 2.(N)      -0.17;     3;     33    -----###################-----
 3.(P)      -4.05;    19;    302     ----#################------
BEST DOUBLE COUPLE:M0=4.1*10**27       --###############------
 NP1:STRIKE= 26;DIP=27;SLIP=  82         ############-------
 NP2:       215;    64;       94                -----------
```

//

OAXACA EARTHQUAKE —30 SEPTEMBER 1999

+ 16:31Z 16.0 N 96.8 W Ms=7.6 Mw= 7.7



Ishocron interval—20 Minutes, Dots: Manzanillo WLS (19.1N, 104.3W) and Socorro Island WLS (18.7N, 110W) Point chosen just off coast nearest the epicenter (white plus sign) as a source of hypothetical tsunami.

COMMENTS

The initial PTWC epicenter for the Oaxaca earthquake, while on land, was sufficiently near the coast to warrant the issuance of a regional tsunami warning/watch message. The surface wave magnitude, at 7.6 however, was just above the threshhold for issuing such a message. This fact, together with no reports of a tsunami from Mexico led to a cancellation of the RWW after only 2 messages were issued. A check of the water level data from the Socorro Island station confirmed that no tsunami was spreading through the Pacific.

The Guerrero-Oaxaca, Mexico, coastline faces a relatively active portion of the Middle America Trench where a number of tsunamigenic earthquakes have occurred in the past. The largest probable tsunami, with a reported maximum run-up of 9.2 meters, resulted from a magnitude 7.8 earthquake near Acapulco in 1909. Other significant tsunamis occurred in the area in 1928 and 1957. The event on 16 June 1928 in Puerto Angel inundated 60 meters inland from the shoreline destroying a warehouse.

OAXACA EARTHQUAKE —30 SEPTEMBER 1999, con't

PTWC ACTION

```
Alarm:September 30, OAXACA, MEXICO, Mw=7.7
  HON lp (long period) – 1642Z
Parameters for RWW Messages:
  Determined at: 1655Z
  Origin time – 1631Z
  Vicinity – Oaxaca, Mexico
  Latitude -   16.0N
  Longitude –  96.8W
  Magnitude – Ms 7.6
Messages:
  RWW#1 – 1659Z
    places warned – 3; places in watch – 2
  RWW#2 – 1756Z
    places warned – 3; places in watch – 3
  RWW#3 – 1833Z   Cancellation

PLACES WARNED, ACTION TAKEN:
Mexico - unknown
El Salvador - unknown
Ecuador - unknown
PLACES IN WATCH:
Panama, Peru, and Chile
```

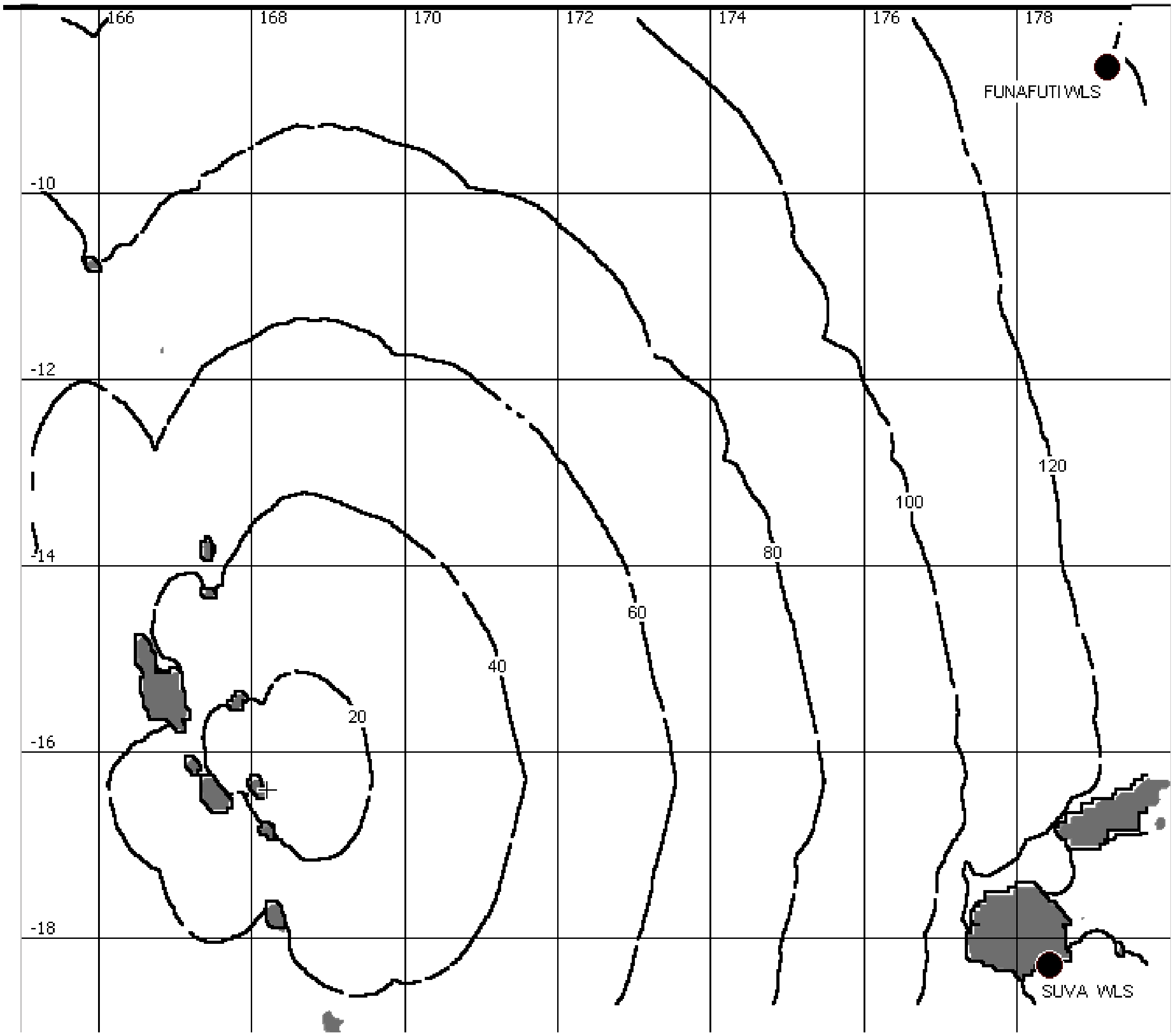
//

HARVARD SOLUTION

```
September 30, OAXACA, MEXICO, Mw=7.7
Natasha Maternovskaya
Goran Ekstrom
CENTROID, MOMENT TENSOR SOLUTION
HARVARD EVENT-FILE NAME C112998A

DATA USED: GSN                               #########-T
  L.P. BODY WAVES:  7S, 19C, T= 45         #############   ###
  MANTLE WAVES:     7S, 17C, T=135       #######################
CENTROID LOCATION:                   ###########################
ORIGIN TIME:      16:31:25.4 0.3     ##-------------##############
LAT 16.23N 0.02;LON  96.97W 0.03    --------------------###########
DEP  53.9 1.2;HALF-DURATION 14.5    -----------------------########
MOMENT TENSOR; SCALE 10**27 D-CM   #-------------------------#######
  MRR=-2.07 0.05; MTT= 1.71 0.04   #------------   ------------#####
MFF= 0.35 0.05; MRT= 0.25 0.06      ##----------- P -------------####
  MRF=-0.35 0.07; MTF=-0.51 0.04    ###----------   --------------###
 PRINCIPAL AXES:                     ####--------------------------#
   1.(T) VAL=  1.92;PLG= 5;AZM= 19    ######-----------------------#-
2.(N)       0.21;     6;    110         ########----------------####
 3.(P)      -2.13;    82;    250        ###########################
BEST DOUBLE COUPLE:M0=2.0*10**27          #######################
 NP1:STRIKE=103;DIP=40;SLIP= -99            ###################
 NP2:       295;    50;      -82                 ###########
```

VANUATU TSUNAMI — 26 NOVEMBER 1999

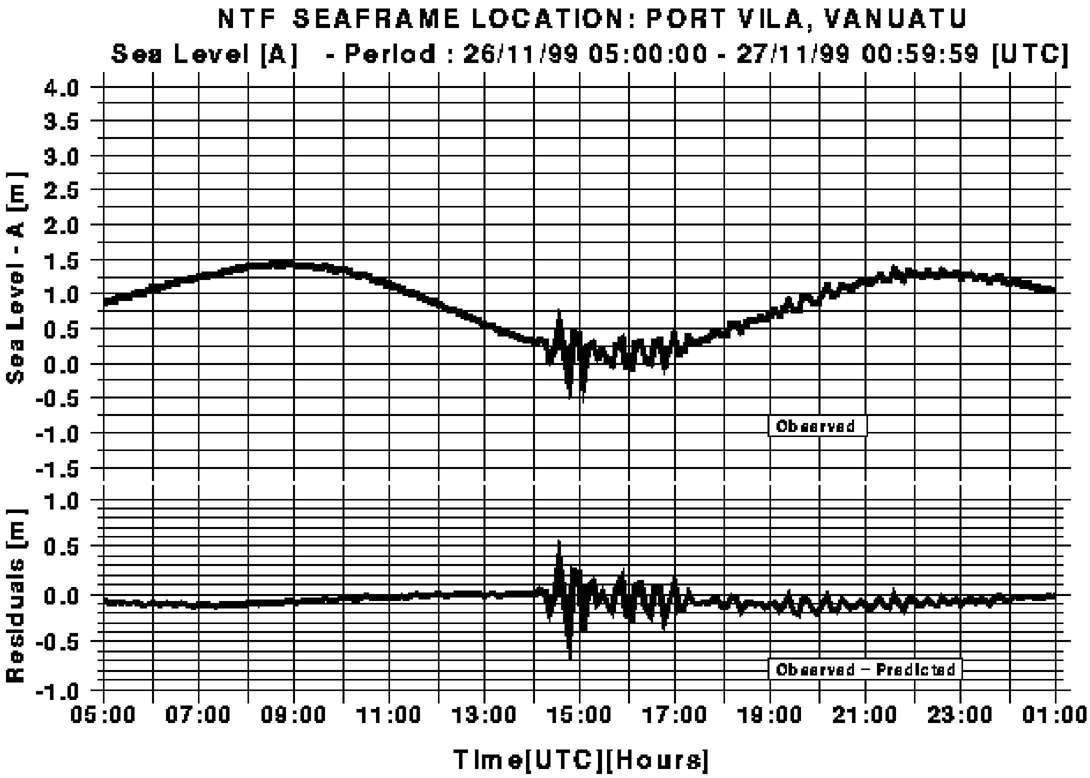


The following information is derived largely from a contemporary report by the Reuters News Service and augmented by information the U.S. National Earthquake Information Center and the Pacific Tsunami Warning Center.

Eight people were confirmed dead, more than 100 were injured, and thousands were left without homes after a major earthquake followed by a tsunami struck Vanuatu at 00:21 Local Time 27 November 1999 (1321 GMT 11/26). The earthquake, centered about 90 kilometers north of Port Vila, the capital, caused extensive damage on the relatively undeveloped Pentecost Island, which has a population of about 12,000. The Vanuatu police joint planning and operations officer reported that eight people were confirmed dead and another two were presumed dead. Boulders and landslides cut off the dirt track linking the scattered population. Communication via the small number of telephones on the island was difficult. Five of the dead were people confirmed to have perished in collapsed building in the central part of the island. Another three were killed after being swept to sea by the tsunami, which was said to have surged two kilometers ashore at the southern end of the island. Another two who were pulled out to sea were never recovered and are presumed dead. More than 100 people were injured and the most seriously injured were flown to hospitals in Port Vila and on neighboring islands for treatment.

The quake measured 7.3 on the Richter scale according to the U.S. National Earthquake Information Center. The Tsunami Warning System in the Pacific correctly did not issue a warning because the earthquake's magnitude was below the threshold for such a warning and, indeed, there was no destructive tsunami in the far field. The Pacific Tsunami Warning Center in Hawaii said the water level measurement station (WLMS) in Suva, Fiji, had recorded a one meter tsunami two hours after the earthquake. The marigram from the WLMS in Port Vila, provided by the National Tide Facility of Australia, appears in this report. This earthquake again demonstrates the need for local or regional ongoing educational programs and rapid-response warning systems in all tsunami prone areas. (MB)

VANUATU TSUNAMI — 26 NOVEMBER 1999



Marigram provided through Australia's National Tide Facility.

POST TSUNAMI SURVEYS:

Moore, A.L. and others, 2000, Report on the damage caused by the 26 November 1999 tsunami in Vanuatu [abstract] Abstracts of papers presented at the STAR Session 2000, Collen &Howorth, eds. South Pacific Applied Geoscience Commission. SOPAC Miscellaneous Report 387.

Pelietier, B. and others, 2000, Le seisme d'Ambrym-Pentecote (Vanuatu) du 26 novembre 1999 (Mw: 7,5):donnees preliminaires sur la seismicite, le tsunami et les deplacements associes. CR Acad. Sci. Paris, Sciences de la Terre et des planetes/Earth and Planetary Sciences 331, 21-28.

SUMMARY OF PACIFIC BASIN EARTHQUAKES 1998

With surface wave or moment magnitudes greater than or equal to 6.5
(data provided by PTWC or NEIC, using Harvard's calculated moment magnitude)

Date (1998)	Location	Time (UTC)	Lat.	Long.	Depth (Km)	Ms	Mw	PTWC Action	Issued (UTC)	Tsu-nami ?
Jan. 4	Loyalty Islands Region	06:12	22.3S	170.9E	101	6.4	7.4	TIB	06:58	no
Jan. 10	Guatemala	08:20	14.4N	91.5W	55	6.2	6.6	-…-	-…-	no
Jan. 12	Near Coast of Central Chile	10:14	31S	71.4W	41	6.2	6.5	-…-	-…-	no
Jan 12	Fiji Islands Region	16:36	15.8S	179.4W	23	6.7	6.7	TIB	17:24	no
Jan 14	Fiji Islands Region	17:24	15.7S	179.3W	15	6.5	6.5	TIB	18:07	no
Jan. 30	Near Coast of Northern Chile	12:16	23.9S	70.2E	55	6.5	7.0	TIB	13:28	no
Feb. 19	Banda Sea	14:15	04.5S	129.1E	17	6.4	6.5	-…-	-…-	no
Mar.20	Auckland Islands Region	21:08	50.0S	163.1E	15	6.1	6.7	-…-	-…-	no
Mar.25	Balleny Islands Region	03:12	62.9S	149.5E	29	8.0	8.1	RWW	04:45	sliglht
Mar.25	South of Australia	12:17	63.6S	147.9E	15	6.1	6.5	-…-	-…-	no
Apr 1	S. Sumatera, Indonesia	17:56	0.5S	99.3E	42	6.2	7.0	-…-	-…-	no
Apr 1	Off Coast of S. Chile	22:43	40.3S	75.0W	15	6.0	6.7	-…-	-…-	no
May 3	SE of Taiwan	23:30	22.3N	125.3E	15	7.3	7.5	TIB	00:19	no
May 13	New Britain Region, PNG	23:02	5.1S	151.7E	45	--	6.6	-…-	-…-	no
May 22	Bolivia	04:49	17.7S	65.4W	15	6.6	6.6	TIB	06:11	no
July 16	Santa Cruz Islands	11:57	11.0S	166.2E	100	6.4	7.0	TIB	12:48	no
July 17	Papua New Guinea	08:49	3.0S	142.0E	10	5.8	7.0	TIB	09:43	yes
July 29	Irian Jaya, Indonesia	18:00	2.7S	139.0E	33	5.9	6.7	TIB	18:58	no
Aug. 4	Near Coast of Ecuador	18:59	0.6S	80.4W	33	6.2	7.2	TIB	19:43	no
Sept 2	Philippines	08:37	5.4N	126.7E	50	6.7	6.8	TIB	09:24	no
Oct 28	N. Molucca Sea	16:25	0.8N	126.0E	33	6.2	6.5	-…-	-…-	no
Nov 9	Banda Sea	05:30	7.0S	129.0E	30	-…-	6.7	-…-	-…-	no
Nov 9	Banda Sea	05:38	7.0S	129.0E	30	7.0	7.0	TIB	06:27	no
Nov 29	S Molucca Sea	14:10	2.1S	124.9E	21	7.7	7.7	RWW	15:07	no

SUMMARY OF PACIFIC BASIN EARTHQUAKES 1999

Date (1999)	Location	Time (UTC)	Lat.	Long.	Depth (Km)	Ms	Mw	PTWC Action	Issued (UTC)	Tsunami?
Jan 19	New Ireland Region	03:35	4.6 S	153.2 E	89	6.4	7.0	-…-	-…-	no
Jan. 28	Fox Islands, Aleutian Islands	08:10	52.9 N	169.1 W	56	6.1	6.6	-…-	-…-	no
Feb. 6	Santa Cruz Islands	21:48	12.9 S	166.7 E	97	7.3	7.4	TIB*	22:31	no
Feb. 22	Loyalty Islands Region	01:00	21.5 S	169.7 E	25	6.4	6.5	-…-	-…-	no
March 4	Celebes Sea	08:52	5.4 N	121.9 E	16	6.5	7.1	-…-	-…-	no
March 8	Off East Coast of Kamchatka	12:25	52.1 N	159.5 E	19	-…-	6.8	TIB	12:57	no
March 20	Andreanof Islands, Aleutian Islands	10:47	51.6 N	177.7 W	49	6.8	6.9	TIB	11:07	no
Apr. 3	Near Coast of Peru	06:17	16.7 S	72.7 W	85	6.2	6.8	-…-	-…-	no
Apr. 5	New Britain Region, PNG	11:07	5.6 S	149.6 E	146	7.0	7.4	TIB	11:47	no
Apr. 13	Fiji Islands Region	10:39	21.4 S	176.5 E	167	-…-	6.8	-…-	-…-	no
Apr. 20	Kermadec Islands Region	19:04	31.9 S	179.0 W	103	-…-	6.5	-…-	-…-	no
May 10	New Britain Region, PNG	20:33	5.2 S	150.9 E	148	6.8	7.1	TIB	21:07	no
May 16	New Britain Region, PNG	00:51	4.8 S	152.5 E	42	7.0	7.1	TIB	01:32	no
May 17	New Britain Region, PNG	10:07	5.2 S	152.9 E	15	6.9	6.7	TIB	10:58	no
June 15	Central Mexico	20:42	18.4 N	97.4 W	60	6.5	7.0	-…-	-…-	no
July 11	Honduras	14:14	15.8 N	88.3 W	15	6.6	6.7	-…-	-…-	no
Aug. 1	Kermadec Islands, NZ	08:39	30.4 S	177.8 W	15	6.4	6.6	-…-	-…-	no
Aug. 20	Costa Rica	10:02	9.0 N	84.2 W	31	6.9	7.0	TIB	10:48	no
Aug. 22	Vanuatu Islands	12:40	16.1 S	168.0 E	15	6.2	6.5	-…-	-…-	no
Sept. 20	Taiwan	17:47	23.8 N	121.0 E	21	7.7	7.7	TIB RWW	18:26 18:30	no
Sept. 20	Taiwan	21:46	23.4 N	121.1 E	33	5.8	6.5	-…-	-…-	no
Sept. 25	Taiwan	23:52	23.7 N	121.2 E	28	6.2	6.5	-…-	-…-	no
Sept. 30	Oaxaca, Mexico	16:31	16.2 N	96.9 W	54	7.6	7.5	RWW	16:59	no
Nov 17	New Britain, PNG	3:28	6.0 S	148.8 E	41	7.0	6.9	TIB	03:53	no
Nov 19	New Britain, PNG	13:56	6.4 S	148.8 E	39	7.0	7.0	TIB	14:43	no
Nov 26	Vanuatu	13:21	16.4 S	168.2 E	20	7.3	7.5	TIB	13:55	yes
Dec 6	Kodiak Island, Alaska	23:12	57.5 N	154.6 W	-…-	6.7	7.0	TIB	23:26	no
Dec 29	Santa Cruz Islands	13:29	11.0 S	-…-	-…-	6.8	-…-	TIB	14:00	no

TIB=Tsunami Information Bulletin, RWW=Regional Watch Warning

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http://www.shoa.cl/oceano/itic/frontpage.html

Located in Honolulu, the **International Tsunami Information Center (ITIC)** was established on 12 November 1965 by the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO). In 1968, IOC formed an International Coordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU). The present 25 Member States are:

Australia, Canada, Chile, China, Colombia, Cook Islands, Costa Rica, Democratic People's Republic of Korea, Ecuador, Fiji, France, Guatemala, Indonesia, Japan, Mexico, New Zealand, Nicaragua, Peru, Philippines, Republic of Korea, Singapore, Thailand, Russian Federation, United States of America, and Western Samoa.

ITIC is responsible, among other functions, for:

Monitoring the international tsunami warning activities in the Pacific and recommending improvements with regard to communications, data networks, data acquisition, and information dissemination;

Bringing to Member States and non-member States information on tsunami warning systems, on the affairs of ITIC and on how to become active participants in the activities of ICG/ITSU;

Assisting Member States of ITSU in the establishment of national warning systems and improving preparedness for tsunamis in all nations throughout the Pacific Ocean;

Gathering and promulgating knowledge on tsunamis and fostering tsunami research and its application to prevent loss of life and damage to property.